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No. 6.

PAPERS

ON

PRACTICAL ENGINEERING,

PUBLISHED BY THE ENGINEER DEPARTMENT,

FOR THE USE OF THE

OFFICERS OF THE UNITED STATES CORPS OF ENGINEERS.

PAPERS ON PRACTICAL ENGINEERING.

No. 6.

REPORT

ADDRESSED TO THE

HON. JEFFERSON DAVIS,

SECRETARY OF WAR,

ON

THE EFFECTS OF FIRING WITH HEAVY ORDNANCE FROM CASEMATE EMBRASURES:

AND ALSO

THE EFFECTS OF FIRING AGAINST THE SAME EMBRASURES WITH VARIOUS KINDS OF MISSILES:

IN THE YEARS 1852, '53, '54, AND '55,

AT

WEST POINT, IN THE STATE OF NEW YORK.

BY

BREVET BRIGADIER-GENERAL JOSEPH G. TOTTEN,
COLONEL AND CHIEF ENGINEER, U. S. ARMY.

WASHINGTON:
TAYLOR AND MAURY.
1857.

War 4198.57

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INTRODUCTORY LETTER.

ENGINEER DEPARTMENT,
Washington, March 1, 1857.

Hon. JEFFERSON DAVIS,
Secretary of War, Washington.

SIR: I have the honor to lay before you an account of some interesting experiments on the resistance to shot and shells, of masonry embrasures, which, on permission and authority granted by you, were made at West Point, in the years 1852–'53–'54 and '55.

With the hearty concurrence and valuable aid of the several officers of engineers who, within that period, held the superintendency of the Military Academy, namely, Capt. Henry Brewerton, Col. R. E. Lee, and Major J. G. Barnard; these experiments were conducted under my instructions, and most of the practical results obtained under my supervision.

The following officers of engineers were employed in the construction of the embrasure targets, or in making notes, and keeping the record of proceedings, or in arranging the papers for the press, namely, Lieuts. Kurtz, Donelson, Gillmore, and Craighill. The drawings, and sketches of effects were, for the most part, made by Lieut. Gillmore, who made up the tabulated record of proceedings, introduced with little or no change in the following pages, and who also introduced into the official record, many beautiful and expressive photographs, taken by his own

hands, of the targets in their successive states of injury and ruin.

Majors G. H. Thomas and Fitz John Porter, of the Artillery, gave in succession very valuable aid in preparing for and directing the firings; which, however, for a portion of the time, were in charge of Lieuts. Donelson and McPherson, of the Engineers.

The results of these experiments, of great importance to the defensive system of the country, are entitled to entire confidence, and are of augmented value, on account of the scrupulous care and exactness with which all details were wrought out by the zeal and intelligence of the above named officers.

Other officers of the army on duty at West Point assisted at different times at the experiments.

The principal objects of the experiments were:—

1st. To ascertain the effects of firing with solid balls, with shells, and with grape and canister, from heavy ordnance at short distances, upon various materials used in the construction of casemate embrasures.

2d. To determine whether these embrasures might have a form that would shut out most of these missiles, and resist for a time the heaviest, without lessening the sector of fire, horizontal and vertical, of the casemate gun.

3d. To determine the degree to which, without injury from the blast of the gun, or lessening its scope of fire, the throat of the embrasure and also the exterior opening might be lessened.

4th. To determine whether all smaller missiles might not be prevented from passing through the throat into the battery; and whether the smoke of the blast of the gun might not also be excluded by simple and easily managed shutters.

Other interesting matters were carefully inquired

into, during the course of the experiments, and all results of interest noted in the record of the firings.

I must not fail to report here that all the work on the targets, except that of masons, stone-cutters, and smiths, and all the labor of moving, mounting, and serving the guns, was done and performed by detachments of the Engineer Company, with great zeal, intelligence, and efficiency on their part, and with a material saving of expense to the government.

For the order of proceedings, the results, and the practical deductions, I refer to the following report.

I have the honor to be,

Very respectfully,

JOS. G. TOTTEN,

B't Brig. Gen. and Col. Engineers.

REPORT

ADDRESSED TO THE

HON. JEFFERSON DAVIS,

SECRETARY OF WAR,

ON the effects of firing with heavy ordnance from casemate embrasures, and also the effects of firing against the same embrasures with various kinds of missiles, in the years 1852–'53–'54 and '55, at West Point, in the State of New York.

CHAPTER I.

INSTRUCTIONS AS TO BUILDING THE TARGETS—DESCRIPTION OF SAME—AND TABLES OF FIRINGS FROM AND AGAINST THEM.

SECTION I.

General Description of the Two Embrasure-Targets.

Two embrasure targets.

1. IT is necessary to state in the first place, that there were two embrasure-targets built, and experimented upon in succession.

General description of first target.

2. The *first*, erected in the summer of 1852, and destroyed by firing against it in the autumn of 1853, consisted of a wall about sixty-seven feet long, ten feet high, and five feet thick; containing six em-

brasures, which are designated in the following pages as Nos. 1, 2, 3, 4, 5, and 6; they are shown on Plate II., Figs. 1 and 2.

General description of second target.

3. And a *second*, of about the same dimensions, erected in 1854, and destroyed in 1855. This target, containing three embrasures, namely, Nos. 7, 8, and 9, is exhibited on Plate III., Figs. 3 and 4.

The particular description of the targets, and the results to each kept separate.

4. As it may conduce to a clearer understanding of the objects in view, the process followed, and the results obtained; the descriptions of the targets, and the tabulated results as to each, will be kept separate, the latter given in the order of proceedings.

Extracts made from Engineer Dept's instructions.

5. And to assist in the explanation, some extracts will be made from the directions issued from the Engineer Department for their construction.

SECTION II.

Instructions for Building First Target—Description of Mortar and different Concretes used.

Extracts from letter to Capt. Brewerton.

6. In the instructions of July 14, 1852, addressed to Capt. Henry Brewerton, then Superintendent of the Military Academy, West Point (N. Y.), it is said by the Chief Engineer:—

Experiments should be made on materials for embrasures.

"I have long deemed it of great importance that "some decisive experiments should be made to ascer- "tain, of the materials generally applicable to the "construction of embrasures for casemate guns, which "is the better in reference to the effect thereon of an "enemy's fire; and I have now obtained the consent "of the Hon. Secretary of War that some experi- "ments of that nature should be made.

A range of 200 yards sufficient.

7. "A range of 200 yards will suffice; and is, per- "haps, the best for the objects in view. These objects "are principally two, namely, to ascertain—

"1st. The effects of solid shot from guns of large "calibre upon different kinds of masonry around the "embrasure, and especially upon the material consti- "tuting its outer edges and the flaring surfaces, and "also the effects upon the throat of the embrasure. 1st object.

"2d. The effect of grape and canister shot upon "the outer surfaces and throat, and the number of "balls that pass, either directly or by reflection, "through the embrasure into the casemate. 2d object.

"And it may be advisable to profit by the oppor- "tunity in making, 3dly, some trials of the effects, "upon the same materials, of shells fired horizontally. 3d object.

8. "In order to the execution of these objects, "there has been prepared in this office, and approved "by the Secretary of War, a drawing of a masonry "target 67′ 8″ long, 5 feet thick, and 10 feet high "above the foundations; containing six gun embra- "sures of dimensions adapted to casemated batteries. General dimensions of target.

9. "*Embrasure No.* 1, being that on the right, "looking at the target, will be made of large blocks "of granite, rough hammered on the faces, but with "well cut beds. Embrasure No. 1.

10. "*Embrasure No.* 2 will be made of cement- "concrete; and will be surrounded by granite ma- "sonry. Both these embrasures (and also No. 6) "are of the general form and dimensions of those "last constructed in the fortifications; and like those "formerly constructed, excepting that the exposure is "made somewhat less, by rounding the junctions of "the cheeks with the sill and lintel. Embrasure No. 2.

11. "*Embrasure No.* 3 is made of cement-concrete; "and is surrounded partly by the same kind of con- "crete, and partly by rubble-stone masonry. The "throat of this embrasure is materially lessened; and "is formed by a mass of wrought iron eight inches "thick, composed of sixteen plates each half an inch Embrasure No. 3.

"thick; and the outer concrete cheeks are notched,
"so as not to present oblique surfaces to an enemy's
"missiles.

Embrasure No. 4.

12. "*Embrasure No.* 4 is made of asphaltic-con-
"crete, and is surrounded by rubble-stone masonry.
"One-half the throat and one cheek are like No. 3.
"The other cheek, including the throat, is provided
"with three wrought iron plates, each 6″ by 2″; the
"cheeks being notched, to expose parts of the surface
"of these plates, in planes parallel to the face of the
"wall.

Embrasure No. 5.

13. "*Embrasure No.* 5 is composed of blocks of
"lead-concrete on one side, and of cement-concrete
"on the other—all being embedded in a brick wall,
"or rather a wall of rubble masonry, faced with
"bricks; both the outer cheeks of this embrasure will
"be notched and supplied with plates of wrought
"iron 6″ by 2″, like those last described in embrasure
"No. 4.

Embrasure No. 6.

14. "*Embrasure No.* 6 will be made of brick work;
"and surrounded by brick work backed with rubble
"masonry.

To lessen expense, certain details to be omitted, &c.

15. "To lessen expense, the details of tongue holes,
"pintle holes, and other matters necessary to the ser-
"vice of guns in embrasures, but not contributing
"to the strength of the wall, will be omitted, except
"in embrasure No. 3; and this must be fitted to re-
"ceive a gun, in order to try the effect of the blast upon
"the throat irons—this being the first experiment to be
"made. Of course the ground behind this embrasure
"must be levelled, and some planks pinned down to
"the earth to serve as traverse circles. It will be
"necessary also, probably, to throw up a small mound
"of earth to receive the balls fired from the em-
"brasure.

Other means to lessen expense.

16. "With the same object of lessening expense,

"the back face of the wall will be laid up of the "cheapest material. This may be rubble masonry, "but if a facing laid with common bricks will be less "expensive, such should be adopted. * * * *

"Behind the target, and at the distance of about three "feet, there should be erected a rough board fence to "show the marks of all balls or fragments that pass "through the embrasures. * * * * A screen to be erected behind target.

17. "The engineer company should construct the "platform for the gun that is to be used against the "target. If you have a 32 pdr. or a 42 pdr., either "will answer. The same company should lay the "plank traverse circles for the casemate gun of em- "brasure No. 3; any gun that you may have mounted "on a casemate carriage will do for this service. I "mean, of course, 24, 32, or 42 pdr., or 8 inch colum- "biad. * * * * Engineer Company to construct gun-platform.

18. "On further consideration it is deemed better "to make one of the outer cheeks of embrasure No. 3 "of bricks; leaving the other cheek as before stated, "of cement-concrete, the sole and lintel being of "cement-concrete." Change in embrasure No. 3.

19. In building the targets, the mortar used in laying the stones and bricks, and in compounding the cement-concrete, was composed of one measure of cement* in dry powder, and one of clean sharp sand. Description of mortar.

20. The "*cement-concrete*" was made by mixing with rather small fragments (say from half a cubic inch to six cubic inches each) of bricks or stones, clear of all dirt, a quantity of the mortar just described, somewhat greater than the measure of the void space in the bulk of fragments. Description of cement-concrete.

* The term "cement" is applied in these notes, as generally in this country, to a material possessing considerable hydraulic energy. The test applied to inspections under the Engineer Department, requires generally that a cake made of pure cement, immersed in water before hardening, shall in a few minutes, support a wire $\frac{1}{10}$th of an inch in diameter, loaded with the weight of one pound.

Asphaltic-concrete.

21. The "*asphaltic-concrete*" was composed of like fragments of bricks or stones, into which was poured, while hot, a quantity of asphaltic mastic rather exceeding the measure of the void spaces—the proportions in the mastic of pure asphalt to the "calcaire," being such that the mastic would retain its form in the face of the summer's sun at West Point.

Lead-concrete.

22. The "*lead-concrete*" was formed of like fragments and in like proportions. The fragments were well heated before being poured into the mould, and the melted lead was added immediately.

Concretes easily applied.

23. There was no practical difficulty in making these blocks of lead-concrete, and asphalt-concrete, in place; giving to them accurate forms and dimensions, with surfaces even, and free from hollows.

Shutters of embrasure No. 3.

23 *bis*. In Figs. *a* and *b*, Plate IV., are exhibited the details of wrought iron shutters that were mounted by hinges upon the iron throat plates of embrasure No. 3.

SECTION III.

Tables, from 1 to 7 inclusive, of firings from and against the Embrasures of 1st Target; and remarks upon Table No. 1.

TABLE No. 1.

FIRING FROM 1ST TARGET, THROUGH EMBRASURE No. 3, TO TEST THE EFFECT OF THE BLAST OF THE GUN UPON THE EMBRASURE.

Gun, 42 pdr.: Length 10′ 9″: Weight 8465 lbs. Casemate Carriage.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Elevation.	Direction.	Remarks—November 11, 1853.
No.	lbs.	lbs.		degrees		
1	42	10	Ball	0	Direct	No effect, except partially closing the shutters. They were found ajar, after the discharge.
2	42	10	Ball	0	8° Oblique	No effect, except partially closing the shutters. The joints between the iron plates and the brick and cement on either side unaltered.
3	42	10	Ball	0	15° Oblique	No effect, except partially closing the shutters. The joints between the iron plates and the brick and cement on either side unaltered.
4	42	10	Ball	0	22° Oblique	The shutters remained open, perhaps because the mound erected in front to receive the shot, being considerably blown away by the previous discharges, the blast was diminished. The joints around, and exterior to, the throat, showed no tendency to open, nor any movement whatever.
5	42	10	Ball	0	30° Oblique	No effect upon the embrasure. One shutter closed after the discharge; the marks left upon the salient of the offsets nearest the shutters, indicated that the tendency of the blast to press them further open must have been very severe.
6	42	10	0	5	Direct	Thick wad of turf instead of Ball. No effect upon the embrasure. The Gunner nearest the piece thought the shutters closed at the discharge and then rebounded. They remained partly open. The marks upon the corners of the nearest offset considerably enlarged, resembling the effects of a blow from a hammer. The straps of the hinges are the only portions of the shutters which can be put in contact with the offsets.

TABLE No. 1—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Elevation.	Direction.	REMARKS—November 11, 1853.
No.	lbs.	lbs.		degrees		
7	42	10	0	5	Direct	Thick wad of turf instead of Ball. No effect upon the embrasure. Some moist clay, of the consistence of dough, was placed (before the discharge) against the exterior of the gorge plate, to show whether the shutters actually closed or not. From this it was ascertained that only one of them closed entirely. They were both found ajar after the discharge. The marks of their concussion against the salient of the nearest offset enlarged.
						N. B.—The particular effect of this series of shots upon the shutters was to strain the straps of the hinges at the rivets nearest the eye, causing the shutters to bind against the gorge plate, and thus prevent their closing perfectly. It was probably occasioned by the blast taking effect partly behind them, through the opening between them and the gorge plate, and tending to force them from their fastenings. The striking of the shutters against the offset may have assisted in producing the same thing. The strain upon the straps of the hinges was confined almost entirely to the lower ones.

Before proceeding to the results of subsequent firings *at* the 1st target, it may be well to remark on those recorded in the table just given.

No injurious effect from blast of gun upon embrasure No. 3.

24. Upon this embrasure (No. 3), of which the outer cheeks were of cement-concrete on one side, and of brick work on the other, no injurious effect whatever was produced by the blast of the gun, when fired directly to the front, or when traversed as much as 30 degrees from the directrix; or when elevated 5 degrees—which was all that the embrasure would allow. In respect to the form, dimensions, and materials, of the embrasure itself, the results were perfectly satisfactory.

Not so, however, with shutters.

25. But it was not so with the shutters. These consisted of two leaves, and were found to be not

strongly enough hinged to the vertical throat irons. Nor were they truly centered on their hinges, even before they were deformed by the firing.

26. It was clearly shown, however, that shutters mounted like these, and as light—however it may prove to be with heavier ones—will, if well centered, always close spontaneously on the discharge of the gun: some device being necessary, however, to keep them from opening again, by rebound.

Shutters, like these, close spontaneously.

27. Moreover, subsequent firing against these shutters—which were made of "boiler iron" half an inch thick—proved them to be too weak to resist, without being deformed, and thereby rendered useless, any missile fired from a large gun, within a short distance, if harder and larger than a musket ball. See in the following tables, the firings Nos. 14, 20, 21, 22, 25, 28, 47.

These shutters too weak to resist missiles harder or larger than musket balls.

28. The tables 2, 3, 4, 5, 6, and 7, which follow, give the effects of firing against the 1st target with large and small canister shot; with grape shot; with musket balls in canisters; with spherical case shot; with solid shot, and with shells.

Tables of firing *against* 1st target.

29. The terms "right" and "left," used in all the tables of firing *at* the target, mean the right and left hand, when looking at the target from the battery.

Terms "right" and "left" in firing *at* the target.

30. In the tables of firings *from* the target, the same terms mean the right and left hand, when looking out of the target embrasures, to the front, at the battery.

Terms "right" and "left" in firing *from* the target.

31. In figures, the single dash at top indicates feet —the double dash, inches; for example, by 3′ 6″, is meant 3 feet 6 inches.

Single dash and *double dashes* over figures.

TABLE No. 2.

FIRING AGAINST FIRST TARGET WITH CANISTER SHOT WEIGHING 1½ LBS. EACH.

Gun 42 pdr., length 10′ 9″, weight 8,465 lbs.
Platform level with bottom of target.
Axis of gun 4 feet above platform.

Total weight of canister 48 lbs.
Number of shot in canister 27.
Mean diameter of each shot 2¼ inches.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 14, 1853.
No.	lbs.		kind.	lbs.	degree.	yds.	at	
8	42	⅛	Can'r.	48	0	200	No. 3	In all, 7 shots struck the target. One tore off the corner of the outer right offset of No. 3, breaking pieces from 5 bricks, but went no further. One struck concrete of No. 3, on the left upper exterior edge, making an impression or crater, 7 inches diameter by 3 inches deep. (Plate V., Fig. 6.) Four struck stone work, producing no effect. One struck left outer edge of concrete of No. 2, making a crater 10 inches diameter by 2½ inches deep. (Fig. 5.)
9	42	⅛	Can'r.	48	0	200	No. 1	In all, 9 shots struck target. Six struck the outside stone surface near Nos. 1 and 2, without effect. One struck on the left exterior solid angle of concrete of No. 3, knocking off an irregular mass about 16 inches high by 9 inches broad. Two, on the right hand lower curved portion of face of No. 1, producing no effect on the stone, but passed in, one making a mark, by ricochet, on the inside lintel; on the screen behind were 13 holes, all made by fragments of these broken shots, all to the left of the axis of embrasure—the extreme one 4′ 10″ distant; they were spread over an area of 4 feet by 3 feet.
10	42	⅛	Can'r.	48	½	200	No. 1	Nine shots struck target. One passed through No. 1 without touching, 8 struck the granite face without effect. One struck concrete key of No. 2, crater 6 inches diameter by 2½″ deep. (Fig. 7.)
11	42	⅛	Can'r.	48	¾	200	No. 1	In all, 9 shots struck target. One on the inside of the upper left hand curved surface; reflected through, making 2 holes in screen with its fragments. One struck concrete face of No. 2, crater 8″ diameter, 1″ deep. Eight struck face of stone work without effect.

TABLE No. 2—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 14, 1863.
No.	lbs.		kind.	lbs.	degree.	yds.	at	
12	42	⅛	Can'r.	48	¾	200	No. 2	Eight shots struck. Two struck concrete of No. 3 on outer face, making holes 10″ diameter and 4″ deep. No other effects.
13	42	⅛	Can'r.	48	½	200	No. 2	Ten shots struck stone facing without effect. One struck concrete face of No. 3, with little. One passed through No. 2 without touching. In all, 11 shots hit target.
14	42	⅛	Can'r.	48	½	200	No. 2	Five shots hit the target. One hit the right cheek of No. 1, without effect on the stone, but passed through in fragments, making 5 holes through screen over a surface of about 3½ feet in diameter, and marking the screen with many smaller fragments, any one of which would wound, and probably some of them kill. One struck No. 3 on right hand offset, breaking off about ½ of two bricks, and stopped. Two struck the shutter of No. 3; they were stopped, producing curved indentations from ½ to ¾ inch deep. One struck left outer edge of No. 2, glanced to the opposite cheek, near throat, and stopped.

TABLE No. 3.

FIRING AGAINST 1ST TARGET WITH CANISTER SHOT OF $5\frac{1}{10}$TH OUNCES EACH.

Gun 42 pdr., length 10′ 9″, weight 8,465 lbs.
Platform level with bottom of target.
Axis of gun 4 feet above platform.

Total weight of canister 48 lbs.
Number of shot in canister 86.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 15, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
15	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 2	*Twenty-three* shots struck the target, and one passed through No. 2 without touching. Effects of principal shots as follows: One struck concrete to the right of No. 2 on the outer face of wall, giving a crater of 3″ dia., 2″ deep. (Fig. 8, Plate V.) One struck concrete key of No. 2, little above lower edge, giving crater 3″ dia., $3\frac{1}{4}$″ deep. One struck concrete to the left of opening of No. 2, giving a crater 3″ dia., and $1\frac{1}{2}$″ deep. Two struck concrete wall, to the right above No. 3, giving a single crater 5″ dia., and 3″ deep. *One* struck right corner of right-hand shutter of No. 3, then glanced to gorge plate, making a slight impression, and rebounded to first offset, knocking off the corners of 2 bricks. Two shots struck to the right of No. 5, in the joint between concrete and brick work, giving craters 3″ to 4″ dia., and 1″ to $1\frac{1}{2}$″ deep. *One* struck exterior portion of right cheek of No. 1, broke, and passed in fragments through the screen, making 5 holes on left of axis, the nearest one 3′ from it. Numerous small holes were made by these fragments in the screen, besides those enumerated.
16	42	$\frac{1}{8}$	Can'r.	48	$\frac{3}{4}$	200	No. 2	*Twenty-nine* shots struck the target, and one went through No. 1 without touching. Principal ones as follows: One struck the left outer edge of sole of No. 1, knocking off a small piece of granite, then glanced up to the roof and stopped. Two shots in the concrete of No. 3, outer face of wall, crater about 4″ dia., and $2\frac{1}{2}$″ to 3″ deep. *One* shot in left outer edge of No. 2, enlarging old fracture. One shot in concrete of No. 3, to the left above, enlarging old crater; and *one* in the asphalt key of No. 4, near the top, giving crater 5″ dia., $1\frac{1}{2}$″ deep. (Fig. 18.)

TABLE No. 3—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 15, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
17	42	⅛	Can'r.	48	¾	200	No. 3	*Forty* shots struck the target. One passed through No. 1 without touching. One passed through No. 2 without touching. Five shots in concrete of No. 2, on outer face of wall, giving craters about 4″ dia., and 1½″ to 2″ deep. (Fig. 9.) *One* shot in concrete key of No. 3, increasing the depth of old crater to 5″. Six shots in concrete of No. 3, outer face of wall, giving craters about 3″ dia., 2″ deep. *One* shot struck the right outer edge of asphalt No. 4, knocking off a mass 7″ high and 4″ broad. One shot struck the right upper edge of asphalt of No. 4, broke off a small piece, then glanced to outer offset, knocked off a corner, and stopped. One in concrete, to left below opening, crater 3″ dia., 2½″ deep. One in joint above, the shot remaining in the fracture. *Two* shots in lead concrete, outer face of wall of No. 5, giving a crater equal in width and depth to the diameter of the ball. (Figs. 20 and 21.) *One* shot struck left cheek near the outer edge, glanced to the first bar, and stopped. Several shots in the brick wall around No. 6, producing craters about 2″ dia., and 1½ to 2″ deep. (Figs. 16 and 17.)
18	42	⅛	Can'r.	48	¾	200	No. 3	*Thirty-five* shots struck the target. One in concrete of No. 2, outer face of wall, giving crater 5″ dia., and 2″ deep. One in concrete sill of No. 3, at bottom, crater 5″ dia., 1½″ deep. (Fig. 10.) One in concrete of No. 3, outer face of wall, near the top. One near the bottom of the asphalt, No. 4, crater 7″ dia., and 2½″ deep. (Fig. 19.) One shot in lead concrete jamb of No. 5, crater, width and depth of diameter of ball very nearly. One shot struck the left throat plate, and stopped, making a very slight indentation on the iron.
19	42	⅛	Can'r.	48	¾	200	No. 3	*Thirty-three* shots struck the target. Two shots in concrete sill of No. 3, outer face of wall, crater 5″ dia., and 1½″ deep. One on the left jamb outer face of No. 3, enlarging the former

TABLE No. 3—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 15, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
								fracture. Three in concrete of No. 3, on outer face of wall, to the left above, two of them forming one crater 10″ to 5″ dia., and 2½″ to 3½″ deep; the third crater 5″ dia., and 2½″ deep. (Fig. 11.) One struck the right outer edge of asphalt of No. 4, 4″ from the edge, producing cracks 7″ or 8″ long, extending to the edge. One shot struck the right outer cheek of No. 6 (brick), and then glanced through the screen, to the left of the axis, without breaking.
20	42	⅛	Can'r.	48	¾	200	No. 4	*Forty-one* shots struck the target. Inside the opening of No. 4 were 5 shots, viz: One shot struck inner right hand offset, at re-entering angle; knocking off a mass 17″ high, 5″ to 6″ broad, and then stopped on gorge plate. One struck right shutter near the bottom, making a slight indentation through the two thicknesses of boiler iron. One struck left shutter (½″ thick) making an indentation ½″ deep, and cracking open the plate. One struck left gorge plate, broke in pieces, making a very slight indentation, but producing no other effect. One shot struck the edge of this plate, then glanced to the left shutter, making a slight indentation. No marks on the screen behind No. 4, or on the inner portions of the cheeks. One shot struck inner right hand offset, knocking off parts of 2 bricks, 4″ in height, then glanced to the gorge plate, where it made a very slight indentation. One on concrete sill of No. 5, knocking off a mass 6″ or 7″ broad, and 2″ to 3″ deep.
21	42	⅛	Can'r.	48	¾	200	No. 5	*Thirty-five* shots struck the target. Two shots struck the inside of No. 3, one of them on the right shutter near the hinge, making a slight indentation, the other on the hook above, then glanced to the gorge plate, then to first offset, and stopped, making a slight indentation on the iron. One shot struck the lap of the right shutter, cut out a piece one-half the size of the ball, glanced to the left shut-

TABLE No. 3—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 15, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
								ter, broke in pieces, but went no further, leaving a small impression on the left shutter. Two shots struck the lead concrete of No. 5 to the left below on exterior surface of the wall, one remained imbedded a little more than its own thickness.
22	42	$\frac{1}{8}$	Can'r.	48	$\frac{3}{4}$	200	No. 5	Forty shots struck the target. Two shots struck the outer corner of concrete in No. 3, glanced and stopped without touching the shutters, knocking off a small portion of concrete. In No. 4, one shot struck the upper corner of the left gorge plate, broke, and then glanced in pieces to the left shutter, and across to the opposite gorge plate, and stopped; very slight impression on the shutter. In No. 4 also one shot struck the asphalt on left hand corner, crater 6″ dia., $2\frac{1}{2}$″ deep. In No. 5, one shot struck concrete cheek, glanced to the middle plate, and was stopped. One shot struck the shutters at their junction, spread them open, breaking two hinges off the right shutter, and strained the left shutter hinges; no marks of further progress. (These shutters are single $\frac{1}{2}$″ plate.) One struck in No. 5 at the upper right corner and stopped. Three shots in lead key with the usual penetration. One in lead joint on the left below, with the usual penetration. One shot struck the right outer cheek of No. 6, broke in two pieces, and passed through the screen at the left extreme range. One struck left outer cheek near the throat, glanced within 2″ of inner opposite corner, and passed through the screen without breaking. Two shots struck the sill near the sole and stopped, knocking off corner of one brick each.

TABLE No. 4.

FIRING AGAINST 1ST TARGET WITH GRAPE SHOT—EACH WEIGHING 4.20 LBS.

Gun 42 pdr., length 10′ 9″, weight 8,465 lbs.
Platform level with bottom of target.
Axis of gun 4 ft. above platform.

Total weight of stand of grape 51¼ lbs.
Number of shot in each stand 9.
Diam. of each shot 3.17 inches.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 15 and 16, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
23	42	⅛	Grape	51¼	½	200	No. 6	4 shots struck the target, one to the left below No. 6, crater 8″ dia. 5″ deep (Fig. 14); shot rebounded—one on the left end of the target, crater 9″ dia. 4½″ deep, cracked a mass 4′ 1″ in height, reaching from the hole to the edge, also a crack from the hole to the top of the wall to the right.
24	42	⅛	Grape	51¼	¼	200	No. 6	4 shots struck the target, one on the outer right corner of sole of No. 6, knocking off a mass 4″ deep and 8″ dia.—one on the outer edge of sole of No. 6, glancing to the upper interior edge, where it made a small cut, and then passed over the screen without breaking. Another shot in the brick work on the outer face of the wall; crater 8″ wide by 4″ deep (Fig. 13); one on the left edge of the wall of the target, cutting out a segment about 5 to 6 inches high and 4 inches broad.
25	42	⅛	Grape	51¼	¼	200	No. 5	6 shots struck the target—one struck concrete sill of No. 5, 1′ below sole, crater 1′ 1″ dia. 4″ deep—one struck the edge of the middle plate, left hand side, glanced to the edge of the throat plate making a small notch about ½ inch deep in each, and then passed through the embrasure, carrying away the right shutter; two hinges of which were previously broken off—one passed directly through the left shutter (½″ iron) of No. 5, knocking a board off the screen behind, and filling the screen with many fragments of the shutter—one struck the right hand centre cheek of No. 6, and glanced through the screen, to the left of axis about 3′, without breaking.

TABLE No. 4—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 15 and 16, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
26	42	$\frac{1}{8}$	Grape	$51\frac{1}{4}$	$\frac{1}{4}$	200	No. 5	5 shots struck the target direct, and 2 by a ricochet, a splinter from the bottom of the stand struck the lead work of No. 5, and stuck there. One struck the brick to the left above No. 5, crater, dia. size of the ball and $2\frac{1}{2}''$ deep, cracking the brick work 8″ or 10″ around.
27	42	$\frac{1}{8}$	Grape	$51\frac{1}{4}$	$\frac{1}{4}$	200	No. 4	3 shots struck the target; one struck the concrete above No. 3, crater 1′ 3″ dia. 3″ deep. (Fig. 12, Plate V.) A mark made on the granite above No. 1, to the left. One struck the lower part of concrete sill of No. 5, at junction with the lead, crater 4″ dia. and 3″ deep.
28	42	$\frac{1}{8}$	Grape	$51\frac{1}{4}$	$\frac{1}{4}$	200	No. 4	6 shots struck the target, one to the left above No. 3, in the concrete, enlarging the old fracture considerably, making it $1\frac{1}{2}'$ or 2′ in length—one in the granite between Nos. 3 and 4, cracking the block slightly, but little penetration—one passed through the left shutter of No. 4, and through the screen, making several holes by the fragments of the shutter—one struck between the concrete and the brick, below No. 5, crater 1′ 3″ dia. and 3″ deep. Others hit the granite but produced no effect.
29	42	$\frac{1}{8}$	Grape	$51\frac{1}{4}$	$\frac{1}{4}$	200	No. 4	5 shots struck the target, one struck the lead concrete lintel of No. 5, crater dia. of the ball, depth $\frac{2}{3}$ dia. of the ball—one struck the outer edge of the concrete sill of No. 5, glanced and struck the upper inner edge, and then passed through the screen without breaking. (Figs. 22 and 23.)
30	42	$\frac{1}{8}$	Grape	$51\frac{1}{4}$	$\frac{1}{4}$	200	No. 4	3 shots struck the target, one struck the iron gorge plate of No. 4, on the right, near the junction with the offset, carrying away part of the offset, and making an indentation on the iron not quite $\frac{1}{2}''$ deep, and was stopped. The other two struck the granite.

TABLE No. 4—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 15 and 16, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
31	42	$\frac{1}{8}$	Grape	51$\frac{1}{4}$	$\frac{1}{4}$	200	No. 3	4 shots struck the target. The only one of interest was in No. 3, where the shot struck the right outer edge of concrete sill, tore out a mass 11″ wide and 6″ high, and then glanced up, and struck the inner offset on the right side, tore off the corners of 4 bricks, and stopped. All the fragments which this shot created were stopped by the shutters.
32	42	$\frac{1}{8}$	Grape	51$\frac{1}{4}$	$\frac{1}{4}$	200	No. 2	Only 1 shot struck the target, viz., on the granite above No. 1, no effect. A fragment passed through No. 2, into the screen, probably from the stand of grape.
33	42	$\frac{1}{8}$	Grape	51$\frac{1}{4}$	$\frac{1}{2}$	200	No. 2	3 shots struck the target. No important effects.
34	42	$\frac{1}{8}$	Grape	51$\frac{1}{4}$	$\frac{1}{2}$	200	No. 2	5 shots struck the target, one directly under No. 1, and cracked the corner off the granite block 8″ or 10″—one struck the top of the brick wall over No. 5, and took off 4 or 5 bricks.
35	42	$\frac{1}{8}$	Grape	51$\frac{1}{4}$	$\frac{3}{4}$	200	Between 1 & 2	6 shots struck the target. The only one of importance, struck the upper outer edge of No. 3, between the brick and concrete, knocking off a mass 7″ broad and 3″ deep. A fragment of the stand passed through No. 2, into the screen, but not through it.
36	42	$\frac{1}{8}$	Grape	51$\frac{1}{4}$	$\frac{3}{4}$	200	Between 1 & 2	5 shots struck the target, and 2 passed through Embrasure No. 1, into the screen without touching. No important effects.
37	42	$\frac{1}{8}$	Grape	51$\frac{1}{4}$	$\frac{3}{4}$	200	Between 1 & 2	5 shots struck the target. The only one of consequence, struck the concrete lintel of No. 2, 1′ above outer edge; crater 1′ wide and 3″ deep, and cracked off a mass 1′ 3″ long and 4″ thick, down to the roof of the embrasure—one in the brick jamb of No. 3; little effect, crater only 3″ dia. and 1$\frac{1}{2}$″ deep. (See Fig. 15.)

TABLE No. 5.

FIRING AGAINST 1ST TARGET WITH SPHERICAL CASE SHOT.

Gun 42 pdr., length 10′ 9″, weight 8,465 lbs. Platform level with bottom of target. Axis of gun 4 feet above platform.

No. of musket balls in each shell 306. Bursting charge of powder 9 ounces.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 16, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
38	42	⅛	S. Case	39	1	200	No. 1	The shell passed through Embrasure No. 1, without touching, and burst a short distance beyond.
39	42	⅛	S. Case	39	1	200	Right cheek, No. 1	The shell struck the angle at the throat, on the right-hand side at the springing of the upper curved surface—burst in the embrasure immediately after striking, carrying away an entire panel of the screen 6′ 4″ wide, and making numerous impressions with its fragments on the ground and bushes beyond. A small piece of granite was broken off the solid throat angle of the embrasure, and numerous marks of fragments on the sole inside of the throat.
40	42	⅛	S. Case	39	1	200	Right cheek, No. 2	The shell struck the angle at the throat, on the right hand side, a little above the springing of the upper curved surface, knocking off a piece 2½″ or 3″ thick and 8″ or 10″ high, burst at striking, and carried away an entire panel of the screen behind, making many impressions on the ground and bushes beyond.
41	42	⅛	S. Case	39	55′	200	Right cheek, No. 2	The shell struck the lintel of No. 2, to the right above, on outer surface of the wall, broke the concrete off for a distance of 3′ horizontally along the lintel, and penetrated 6″—shell exploded as it struck, throwing numerous fragments, through the embrasure, and carrying away a portion of the screen 3′ 10″ square. (Figs. 31 and 32, Plate VII.)
42	42	⅛	S. Case	39	55′	200	Right cheek, No. 1	The shell struck 7″ to the right above on lintel of No. 1, outer surface of wall, penetrated about 1″, and cracked off a piece of granite 1′ 6″ long and 8″ high, extending under the edge about 4″ or 5″, cracking the lower sur-

TABLE No. 5—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 16, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
								face for 1′ inside of the edge, caused a slight movement in the joint, at the springing of the upper right curved surface, from the front to rear of the wall, and continuing on the inside from the embrasure diagonally up to the top of the wall.
43	42	$\frac{1}{8}$	S. Case	39	50′	200	Centre of No. 1	The shell struck the right cheek of Embrasure No. 1, at the springing of the lower curved surface—exploded as it struck, and glanced in numerous fragments to the screen, carrying away two entire panels. It opened the joint where it struck, moved the stone slightly in, and cracked the joint on the inner cheek, at its junction with the brick work, down to the sole.
44 and 45	42	$\frac{1}{8}$	S. Case	39	50′	200	Centre of No. 6	60 musket balls struck the target from both discharges. Both shells exploded immediately after leaving the piece. There were 7 musket balls inside of the opening of No. 5, all of which were stopped by the offsets; 2 went through No. 5, without touching. 4 musket balls inside of the opening of No. 6, all deflected inside to the screen. They would have been arrested by an embrasure with exterior offsets—1 musket ball struck the cheek of No. 5, and stopped.
46 and 47	42	$\frac{1}{8}$	S. Case	39	50′	200	Centre of No. 3	No. 46 burst immediately after leaving the piece; many fragments from the shell, and also many musket balls struck the target. No. 47 struck the left shutter of No. 3, at its junction with the gorge plate, cut out of the shutter a segment of 9″ high and $2\frac{1}{2}$″ broad, knocked off a piece of concrete from the solid angle behind the gorge plate, 9″ broad, extending from the sole to the roof, made an indentation on the 8″ gorge plate $2\frac{1}{4}$″ to $2\frac{1}{2}$″ deep, and caused a material bending of the whole plate; it also carried away both offsets from the sole to the roof on the left. The shutters were both left on their hinges. (See Fig. 24, Plate V.)

TABLE No. 5—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 16, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
								From No. 46, ten musket shots struck within Embrasure No. 4, and were stopped by the offsets. Two musket shots passed through, without touching, into the screen. All that struck No. 3, from the 46th round were stopped by the shutters and offsets.
48	42	$\frac{1}{8}$	S. Case	39	50′	200	Left cheek, No. 4	Struck 6″ to the left, of the left outer edge of the asphalt cheek of No. 4, penetrated 7″, dia. of crater, 2 ft. broke the round anchoring bar of the outer plate, and exploded, doing no more damage. Embrasure left still in good condition for service. (Figs. 25 and 26 of Plate VI.)

TABLE No. 6.

FIRING AT 1ST TARGET WITH MUSKET BALLS IN CANISTER.

Gun 42 pdr., length 10′ 9″, weight 8,465 lbs.
Platform level with bottom of target.
Axis of gun 4 feet above platform.

Total weight of canister 48 lbs.
Number of balls in canister 736.
Balls of lead 18 to the pound.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 18, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
51	42	1/8	Can'r.	48	1	200	Between 5 & 6	5 musket balls struck the inside of the opening of No. 5, and were stopped by the offsets; two passed through into the screen without touching. 5 musket balls struck the inside of the opening of No. 6, and were carried inside by deflection from the cheek; the marks of 4 of them were found upon the screen. 3 musket balls struck inside of the opening of No. 4, and were stopped by the offsets; 2 went through into the screen without touching. 1 stopped by the offset in No. 3, and 1 passed through embrasure No. 3 without touching. 1 passed through No. 2 without touching.
52	42	1/8	Can'r.	48	1¼	200	Between 5 & 6	13 musket balls struck the cheek of embrasure No. 2, and were deflected inside, and 7 passed through without touching.
53	42	1/8	Can'r.	48	1¼	200	Between 5 & 6	18 musket balls struck within the cheeks of No. 3, and were stopped by the offsets, and 6 passed through without touching.
54	42	1/8	Can'r.	48	1½	200	Between 2 & 3	10 musket balls struck within the cheeks of No. 4, and were stopped by the offsets, and 9 passed through without touching.
55	42	1/8	Can'r.	48	1½	200	Between 2 & 3	13 musket balls struck within the cheeks of embrasure No. 5, and were stopped by the offsets, and 3 passed through without touching.
56	42	1/8	Can'r.	48	1¾	200	Between 2 & 3	3 musket balls struck the cheeks of embrasure No. 6, and were deflected, and 3 passed through without touching. 5 musket balls were deflected to the screen, by the cheeks of embrasure No. 1. 3 musket balls passed through embrasure No. 1 without touching.
								NOTE.—All the balls that struck within the opening of the embrasures without offsets, passed through either directly or by deflection. In those with offsets, 41 out of 59 were stopped by the offsets. 18 passing without touching.

TABLE No. 7.

FIRING AT 1ST TARGET WITH SOLID BALLS AND SHELLS.

Gun 42 pdr., length 10′ 9″, weight 8,465 lbs. Platform level with bottom of target. Axis of gun 4 feet above platform.

Weight of ball 42 pounds.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	Remarks—November 16, 18, and 23, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
49	42	¼	Solid ball	42	½	200	Left cheek No. 5	Struck the left outer edge of the cheek of No. 5, lapping on the outer face of the wall about half the diameter of ball, diverted a very little to the right, struck the outer plate, at the centre, tore out a piece of 1′ high and 4″ wide, broke, and one piece glanced to the inner opposite cheek, making a slight mark on the concrete; two or three other pieces flew against the opposite cheek. The iron plate, besides being broken, was jarred, one of the round anchoring bars being broken. The whole left cheek of the embrasure was jarred, showing a crack in the brick work on the inside, extending from the sole to the roof. The wall was also cracked above the embrasure on the inside. Embrasure still serviceable. Figs. 27 and 28, Plate VI.
50	42	¼	Solid ball	42	½	200	Left cheek No. 5	Struck the left throat plate, cutting out a piece about one-third the area of the ball, bent the plate slightly, and jarred it in its position. Embrasure still serviceable. (See Figs. 27 and 28, at *o* and *o′*.)
57	42	¼	Solid ball	42	½	200	Granite cheek block No. 1, left side	Shot struck the face of the lower stone on the left cheek, crater 2′ 4″ and 3′ dia., and 4″ deep, cracked the stones, according to the sketch, loosening all the bed of this stone and also the one above it, and shaking in its bed the sill stone of the embrasure. The interior face of the wall behind was also considerably cracked. The ball was broken. (See Plate VIII., Fig. 35, at *A*.)
58	42	¼	Solid ball	42	½	200	Granite cheek block No. 1	Shot struck the block of granite between Nos. 1 and 2, in the same course with the sill stone. Crater 2′ 2″×1′ 4″ dia., and 4″ deep; cracked the stone as seen in the sketch,

TABLE No. 7—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 16, 18, and 23, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
								loosening the beds entirely through the wall, enlarging the cracks caused by the former discharge on the adjoining stone. The cracks in the rear of the wall show a decided effect upon the stones on that face. Shot broke. (See Fig. 35, Plate VIII., at *B.*)
59	42	¼	Solid ball	42	½	200	Between 1 & 2	Shot struck the outer face of the granite block forming the left cheek of embrasure No. 1, 4¼″ penetration, carried away a large mass of the stone, extending 9″ inside of the throat, and varying in thickness from 1′ 3″ at the outer edge, and 4″ to 6″ towards the throat, and loosening the brick work inside entirely through the wall, and enlarging the cracks that were there before. Shot broke. For a side view of the effects of the last three shots, viz., 57, 58, and 59, see Plate VIII., Fig. 36.
60	42	¼	Solid ball	42	½	200	Between 1 & 2	Shot struck the stone as before, very little higher up, increasing the former crater, driving the cheek stone in 2″, and breaking the interior brick work to some extent, and enlarging the cracks on that side to the top of the wall. From near the bottom of the crater, a considerable crack extends entirely through the stone to the opposite side. Shot broke.
61	42	¼	Solid ball	42	½	200	Left cheek No. 2	Shot struck near the edge of the granite block on the left of the concrete, turned aside into the concrete, and knocked out a mass 2′ 6″, and 2′ broad, and 9″ deep; penetration into the granite about 2″.
62	42	¼	Solid ball	42	½	200	Left cheek No. 2	Shot struck to the left below, a few inches from the curve, penetrating 1′ 9″, and breaking away a mass reaching to the gorge, where it measured 10″ broad at the sole, and 1′ 6″ high, and cracking the concrete on the inner cheek as far as the brick wall. The other cracks on the inner face of the wall were somewhat enlarged. Some fragments of considerable size were carried through,

TABLE No. 7.—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 16, 18, and 23, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
								one measuring about 7″ cube. There were also numerous smaller ones, only one of which went with sufficient force to penetrate the screen. The ball was not broken, but rolled in through the embrasure apparently with no force. For effects of shots 61 and 62 see Plate VII., Figs. 33 and 34.
63	42	¼	Solid ball	42	½	200	Right cheek, No. 3	Shot struck the right gorge plate, near the top, made an indentation about 2″ deep, tore the plate from its fastenings, lifting the inner half of the plate entirely from its bed, and sending it completely through the embrasure, leaving the other in an inclined position near its place, and the embrasure unserviceable. The inner and outer portions of the plate were connected together by only two ⅝″ bolts. The anchoring bolt at the top was broken, and the concrete backing carried away. The inside of the embrasure was but little injured. The bending of the plates was perceptible through the entire thickness of 8″. This embrasure was defective, the gorge plate being imperfectly anchored, and weakly put together.
64	42	¼	Solid ball	42	½	200	Right cheek, No. 5	Shot struck near the right outer edge of No. 5, a little below the springing of the upper curve, knocking off a mass of concrete (and shaking the concrete for a considerable distance) 2′ 4″ high, and 1′ broad, struck, and broke off in 3 pieces, all the straight portion of the outer offset plate, and penetrated to the second plate, which remained uninjured. Full one-half of the ball struck against the outer plate, breaking one anchor from each plate. The upper and lower curved portions of the plate remained intact, or nearly so. The embrasure still serviceable. The shot broke. Cracks were made on the inner cheek and face of the brickwork. (Plate VII., Figs. 29 and 30.)

TABLE No. 7—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 16, 18, and 23, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
65	42	¼	Solid ball	42	½	200	Left cheek, No. 6	Shot struck to the left above, about 8″ from the edge of the opening, penetrated 1′ 10″, knocked off a mass of brick work 3′ 6″ high, and 2′ 2″ broad; also, the head of the arch was knocked off to the depth of 10″, and height of 1′ 5″. From the crater, extending to the end of the wall, the brick work was entirely shattered, large cracks extending diagonally to the top of the wall and horizontally to the end. On the inside of the throat, a great deal of the arch fell in, and large cracks were made in the stone work in various directions. The brick work about the throat was much shattered. *The shot did not break.* (Plate VIII., Fig. 37.)
66	42	¼	Solid ball	42	½	200	Right cheek, No. 4	Ball struck the gorge plate near the top 4½″ from a vertical line through the centre of the embrasure; tore the plate from its fastenings, breaking the anchoring irons, made of ⅝″ round iron, and separating it from the side of the embrasure, 5″ at top and 2″ at bottom. Tore away the top of three of the ½″ plates, bending all the others, driving the top in 1½″, and knocking off the asphalt on the inner face of the embrasure all along the gorge plate, and extending back 8″. The whole soffit of the inner part of the embrasure was shaken, and a portion of the brick masonry on the inner edge of the sole 2′ in length, and extending back towards the throat 7″, was torn away. The two bolts connecting the inner half of the gorge plate with the outer, were broken, and part of the door knocked off, doing it no other damage than breaking the hinges.
67	42	¼	Solid ball	42	½	200	Left cheek, No. 5	Ball struck where it was aimed. Crater 1′ 2″ to 1′ 3″ dia., and 1′ deep. The ball was cracked and fell back. The inner cheek was considerably damaged, a large crack extending up and down the cheek about 9″ from the inner edge. This shot affords a fair test of the penetration of 42 lbs. solid shot in lead concrete. (Plate VIII., Fig. 43.)

TABLE No. 7—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 16, 18, and 23, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
68	42	¼	Solid ball	42	½	200	Brick between 5 and 6	Struck where it was aimed. Crater 2′ 4″ dia., 2′ ½″ deep, the lower half of which was a little larger than the size of the ball. The stone backing in the rear of the wall was started in about 1″. (Plate VIII., Fig. 38.)
69	42	¼	Solid ball	42	½	200	Right outer face, No. 5	Shot struck in the brickwork to the right below. Crater 2′ 6″ and 2′ 9″ dia., and 1′ 6″ deep. The effect of the shot was also shown on the opposite face of the wall, by cracks in the stone backing, extending 18″ or 2′ in height. The ball was not broken.
70	42	¼	Solid ball	42	½	200	Right outer face, No. 5 opposite centre of lintel.	Shot struck the lead concrete lintel near its junction with the hydraulic concrete jamb, was deflected slightly downwards and penetrated 1′ 4″. It was stopped by the middle offset plate, which was not moved from its position. The crater extended to the roof of the embrasure. No fragments of consequence passed through. The brick work on the inner upper edge of the embrasure was jarred, and to some extent displaced. The effect of this shot does not show the actual penetration into lead concrete, as it struck near the hydraulic concrete, and not far from the roof of the embrasure. The ball was broken. (Plate VIII., Fig. 42.)
71	42	¼	Solid ball	42	½	200	Left outer face, No. 4	Shot passed through without touching.
72	42	¼	Solid ball	42	½	200	Left outer face, No. 4	Shot struck about one foot below the centre of the jamb, just to the left of the outer offset plate, was deflected slightly to the right, penetrated 1′ 4″, and passed out between the two outer offset plates, forcing the bottom of the outer plate out, and producing large cracks in the asphalte concrete sill, extending entirely to the bottom. The offset plates remained in their position, though little or no asphalte remained between them. The ball was not broken. The shock extended to the inner cheek, cracking the asphalte and brickwork to a considerable extent.

TABLE No. 7—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 16, 18, and 23, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
73	42	¼	Solid ball	42	½	200	Left cheek at offsets No. 4	Shot struck the asphalte concrete lintel just above the end of the outer offset plate; penetrated 1′ 4″ to the upper end of the second plate, passed down between the two plates, leaving the outer one merely hanging by the anchors, the asphalte being entirely removed from behind and around it by this shot and No. 72. It knocked off a mass of asphalte from the lintel 2′ 4″ wide horizontally, and extending upwards to the granite. A crater existed in the left jamb of No. 4 before these shots. See 48th shot.
74	42	¼	Solid ball	42	½	200	Left cheek, No. 3 gorge plate.	Shot struck where it was aimed—carried away the gorge plate, separating it vertically into two pieces, breaking all the anchor bolts, and leaving the embrasure unserviceable. The shot broke into pieces, but did no damage to the screen. The fragments of the plate were left in the embrasure. By removing them, the gun might still be served.
75	42	¼	Solid ball	42	½	200	Left outer face, No. 2	Shot struck where it was aimed, passed through, glancing to the right, and enlarging the old crater in height and width. The ball passed through the screen without breaking, and was found at a distance of 30 or 40 yards to the right and rear. A large crater existed from 61st and 62d shots—which see.
76	42	¼	Solid ball	42	½	200	Right outer cheek, No. 2	Shot struck where it was aimed, 5″ inside of the right outer edge, passed straight through, making a curved cut in the cheek 1′ 8″ high, and 11″ broad at the middle, cracked the concrete on the right outer face in two pieces, out to the stone work. On the inner cheek the brick backing, as well as the concrete, was considerably cracked and displaced. An entire panel of the screen was carried away. The ball cut down a tree 4″ or 5″ in dia., at a distance of 40 or 50 yards in the rear.

TABLE No. 7—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 16, 18, and 23, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
77	42	¼	Solid ball	42	½	200	Left outer cheek, No. 1 in old crater.	Shot struck below where it was aimed about 1′ 6″, and on a line with the sill, widening and enlarging the former crater. A large piece of the sill was broken off 1′ 8″ wide horizontally, and 5″ deep. (See 80th shot, below.)
78	42	¼	Solid ball	42	½	200	Same as No. 77	Shot struck a little to the left of the mark, on a level with the sole of the embrasure, enlarging the former crater, making it 1′ 8″ deep where the ball struck. (See 80th shot, below.)
79	42	¼	Solid ball	42	½	200	Right outer cheek, No. 1	Shot struck 3″ or 4″ above the centre of the cheek, broke off a piece of the solid angle at the throat 8″ high, 1′ 2″ wide and 6″ deep, cracking the cheek stone from top to bottom, and breaking off a fragment from its outer edge 1′ 3″ wide, and 8″ deep; also a piece very nearly the same size from the stone above. The shot broke and passed in fragments through the screen, carrying away a portion 4′ by 4′ 6″, and scattering fragments of granite to some distance.
80	42	¼	Solid ball	42	½	200	Left outer cheek, No. 1	Shot struck where it was aimed, and passed through the embrasure, carrying with it the remnants of the left cheek stone, and enlarging the width of the opening at the throat 1′ 8″. The shot broke, and with the fragments of granite, passed through the screen, carrying away nearly three panels. A large crater existed from shots 57, 58, 59, and 60. (Plate VIII., Fig. 39.)
81	42	¼	Solid ball	42	½	200	Right outer face, No. 2	Shot struck the concrete sill, glanced upwards, carrying away all that portion of the sole from the outer edge to the throat, and fell inside. The shot was not broken. Craters existed from 61st, 62d, and 75th shots on right and left outer cheek.
82	42	¼	Solid ball	42	½	200	Concrete wall above No. 3	The shot struck 1′ 9″ above the upper edge of the embrasure, glanced downwards, carrying away all the key of the embrasure as far in as the brick

TABLE No. 7—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—November 16, 18, and 23, 1853.
No.	lbs.		kind	lbs.	degrees	yds.	at	
								work on the inner face of the wall; the shot was not broken, but remained on the sole of the embrasure. The concrete was cracked in various directions as far as the top of the wall. (Plate VIII., Fig. 41.)
83	42	$\frac{1}{4}$	Solid ball	42	$\frac{1}{2}$	200	Outer right face, No. 4 asphalte	Shot struck between the asphalte and granite, glanced a little downward, and penetrated 1′ 2″ into the asphalte, knocking off the outer face of the asphalte key to a depth of 10″ or 11″ and bringing down two large pieces of granite from above where the shot struck. The shot was not broken. (Plate VIII., Fig. 40.)
84	42	$\frac{1}{4}$	Solid ball	42	$\frac{1}{2}$	200	Outer right face, No. 4 asphalte	Shot struck to the right below, in the granite near the asphalte. Shot broke. (Fig. 40.)
85	42	$\frac{1}{8}$	Shell	$31\frac{3}{4}$	1	200	Granite on the right of the Target.	The shell burst soon after it left the piece.
86	42	$\frac{1}{8}$	Shell	$31\frac{3}{4}$	1	200	Same as No. 85	Shell struck the granite masonry on the second course from the top, near the corner, knocking off one stone of the top course, and displacing those near the corner.
87	42	$\frac{1}{8}$	Shell	$31\frac{3}{4}$	1	200	Outer face of lead concrete No. 5	Struck the brickwork. Crater 2′ dia. by 1′ deep. The shell broke by the concussion.
88	42	$\frac{1}{8}$	Shell	$31\frac{3}{4}$	1	200	Outer face of lead concrete No. 5	Struck the lead concrete jamb near its junction with the lead lintel. Penetrated $8\frac{1}{2}$″, width of crater 1′ 4″. Knocked off a large mass of brick work above, to the depth of 18″ or 20″, extending to the top of the wall. The shell exploded in the crater.
								NOTE.—A shell without a fuze, was fired against the granite, and exploded on striking.

SECTION IV.

Instructions for Building 2d Target, and Remarks in relation to Materials used in the Construction.

32. Before proceeding to practical deductions from the experimental firings given in the foregoing tables, it seems best to give, in similar tables, the firings from, and at, the 2d target.

Before deductions as to 1st target, are given tables, &c., for 2d.

The peculiarities of this 2d target were partly consequent upon the results afforded by the trials of the 1st.

The following extracts from directions given as to this second target will, with the plates and figures, sufficiently explain the construction, form, and dimensions of all its parts.

LETTER TO COL. LEE.

ENGINEER DEPARTMENT,
Washington, 5th May, 1854.

"Bv't Col. R. E. LEE,
Corps of Engineers, Sup't and Comd'g Mil'y Academy,
West Point, N. Y.

33. SIR: The gunnery practice upon the embrasure target at West Point, has afforded several important results in reference to the form, dimensions, and materials, proper for sea-coast embrasures; still there are some other matters not fully settled that are of not inferior importance—and before we draw up a final report to the Secretary of War, I desire your further assistance in clearing these from doubt.

Further assistance of Col. Lee desired.

34. I now send the drawing of an embrasure to be made of granite and iron; and have to ask your aid, in putting it immediately under construction.

Drawing sent. See Plate III., embrasure No. 7.

35. There is nothing obligatory in the exterior gra-

Exterior apparell of embrasure.

nite appareil of the drawing, except of the embrasure itself; above, below, and on the sides, the courses may be arranged to suit stones on hand, or such as can be most easily procured.

Interior face.

36. The interior face, with the same exception, is supposed to be of bricks; it may be of rubble masonry.

Heart of wall.

37. The heart of the wall is to be of concrete, in the following proportions: The measure of mortar to be twice the measure of void space—the latter being reduced to a minimum nearly, by the use of fragments of various sizes.

Composition of mortar.

38. All the mortar should be composed of cement in dry powder—1 measure to 1 measure of clean sand—except in laying the stones or bricks composing the embrasure, and this should be of cement in paste 2, to 1 of sand.

Time of making mortar.

39. All the mortar in which cement enters should be made at the moment of using it, and no cement should be used of which the test cake required more than a few minutes to bear the pound weight.

Sill-stones.

40. The drawing shows the outer, and the inner, sill-stones of the embrasure—the latter being connected with the stone beneath it by two cast-iron dowels which, besides being closely fitted to their holes, should be leaded, by pouring down lead through small holes drilled through from the top stone. These sill-stones, besides being prepared for the head of the pintle bolt, will have cut in them, recesses for the lower ends of the cast and wrought-iron jambs. This is the place to state that these jambs will be composed first, of a mass of wrought-iron 4″ × 10″ and 3′ 3″ high, composed of eight thicknesses of boiler iron, fastened into one mass by a sufficient number of rivets; and secondly, of a mass of tough cast iron of irregular section (as seen in the drawing), and 3

feet 6 inches high, fitting tightly to the back of the wrought-iron mass. These iron jambs being placed erect in the appropriate recesses, and accurately adjusted, will be leaded therein. You may find it advisable to interpose a thin sheet of lead between the two.

41. The figure shows the first course of cheek stones, as they embrace the iron jambs. The inner cheek stones embrace also, for a depth of six inches, the inner sill stones, and cannot be moved inwards, without taking with them the sill stone, and a still larger stone beneath. These outer and inner lower cheek stones are connected by cast-iron dove-tailed cramps 10 inches long and 2 inches thick—they are also prepared for connection with the second course of cheek stones by cast-iron dowels. Pains should be taken to secure the tight and accurate fitting of all such dowels.

1st course of cheek stones.

42. It will be noticed that there is to be a shutter of two leaves, to be made of three thicknesses of half-inch boiler iron. The form and dimensions are fully shown. It is to turn on two gun-metal pivots (one above and one below) imbedded in, and riveted to, the iron; which pivots fit accurately into composition boxes, firmly leaded into the sill and lintel. These shutters should be accurate in form, so that they may fit solidly against the proper surfaces when shut, and also when fully open; there will then be little danger of their being deformed when struck by any but a large shot. They should, moreover, be truly centred, so as to move with facility; for if this be the case, they may be expected to shut spontaneously, on the discharge of the gun. To meet this result, or at any rate to provide a simple mode of fastening, a gun-metal latch is devised to be placed at the lower corner of each leaf. The movable part of this latch will

Shutters. See Plate IV., Figs. c, d, e, f, g.

rest on the sill of the embrasure when the shutter is open; as it closes, this part will rise over a gun-metal catch, firmly fastened into the stone sill: it will pass beyond the catch about an inch, so that there may be time for it to fall before reaction can send the shutter the other way.

Concave surface of sill of throat.

43. You will notice a concave conical surface cut, at the throat of the embrasure, in the top of the outer sill; this will allow room for the tulip of the gun, as it traverses, when depressed.

Dimensions of exterior opening and throat reduced.

44. In this embrasure, both the height and breadth of the exterior opening, and of the throat, have been materially reduced; and it would be a great gain to be able to adhere to these dimensions, which, it is hoped, may with care be done. It is in the throat where there must be the greatest accuracy; and it is hoped, moreover, that with attainable accuracy at the throat, there may be a still greater reduction of the exterior opening—this will depend, however, on the effect of the blast, when the gun is fully traversed. In this design, the ball will pass within about 1½ inches of the corner of the shutter, and the outer edge of the embrasure; if we find this proximity does no harm, we may possibly approach still nearer. To keep the ball from going nearer than it ought, and the blast from doing any unnecessary injury, it is indispensable that the axis of the pintle should be exactly right. But that alone will not be enough—there must be no room for play in the tongue of the carriage around the pintle—there should probably be a bushing fitted to the tongue hole, so that it shall embrace the pintle closely.

Axis of pintle should be exactly right.

We may indeed even then find that the carriage is in itself untrue, to an extent forbidding so narrow a throat as we are about to try.

Traverse circles.

45. There are to be traverse circles laid for this

embrasure, because very important trials are to be made by firing from it with an 8-inch Columbiad. I need not say that these circles should be laid with exactness and solidity.

Cutting of the granite blocks.

46. The exterior facing of the granite embrasure may be cut quite roughly; the facing towards the embrasure should be rather finely cut—the beds, and other surfaces in contact, should be truly cut, though not finely—that is to say, hollows of moderate size will be of no consequence. The contact of the granite with the iron jambs should be very carefully attended to, as also iron with iron; to which end, the rivets of the wrought-iron mass, and the shutters, should be countersunk flush.

Wall containing the embrasure.

47. The wall containing this embrasure may be the rebuilt portion of the granite end of the former target, and of the same height. I would, however, carry the granite wall as much as ten or twelve feet westward of the embrasure—building the inner face and heart, as before mentioned, as I desire to fire against a five feet wall of that construction, a few solid shot of large calibre under the highest velocity. Supposing you have no 10-inch Columbiad, I think the trial quite important enough for you to call at once for one to be added to your battery—ships are likely to use even larger guns than these.

Obliquity of wrought-iron jambs.

48. It will be noticed in the section, that the wrought-iron jamb stands a little obliquely to the plane of the throat; this obliquity might be greater with advantage as respects support to this jamb from the interior cheeks of the embrasure; and without danger as to the deflection of small shot into the embrasure; but it would involve a form of shutter not favorable to resistance; even the slight inclination I have in this case given to the jamb, requires, for a

shutter at all arched outward, a little recess to be cut for it in each outer cheek.

Cast-iron backing.

49. I am in hopes that the form of the cast-iron backing will transfer any effect advantageously to the stone behind it.

Rivets of shutter pivots.

50. The heads of the rivets of the pivots of the shutter should be countersunk on the side next the jambs, so as to be flush. Being put through from that side the shutters should then be closed, and then the outer ends be riveted down without any countersinking on that side; this will allow the shutters to be dismounted by mere cutting off these rivet heads. Of course there must be slight depressions cut in the granite to receive the protuberances.

Understanding with Lt. Gillmore as to details.

51. I had an understanding with Lieut. Gillmore while he was here lately, as to many of these details, and should be glad if he could be charged with the duty of constructing the target.

The closest economy enjoined.

52. The person in charge must observe the closest economy consistent with good materials and workmanship, using, as far as possible, the old materials, and also the labor of the engineer company.

A drawing, and southern bricks to be sent.

53. I shall send shortly a drawing of a brick embrasure; and I have ordered to be sent to West Point from Charleston (South Carolina) 3000 of the kind of bricks used at Fort Sumter—these express very well the general quality of southern bricks; and it is very important to know their value in the construction of embrasures, since that part of the country affords no durable stone.

Distance of 10 inch gun.

54. In order the better to try the effect of heavy balls upon the masonry, it would be well to place the 10-inch gun at a distance not greater than 200 or 300 feet from the target, and I assume that this may be done without raising the gun much above the surface of the ground.

55. The platform might be now prepared. The firing generally to be from the old platform. Platform.

I am, very respectfully, sir,

Your ob't serv't,

(Signed) JOS. G. TOTTEN,
Br't Brig. Gen'l and Col. Engineers.

LETTER TO COL. LEE.

ENGINEER DEPARTMENT,
Washington, 20th May, 1854.

Br't Col. R. E. LEE,
Corps of Engineers, Sup't and Com'd't Mil. Academy,
West Point, N. Y.

56. SIR: I now send plans, sections and elevations, of an experimental embrasure, which I desire to have constructed by the side of the one of which I lately sent drawings. *That* was to be faced, and generally constructed with granite. This will be generally of brickwork. Plans, &c., of brick embrasure sent. See Plate III., embrasure No. 8.

57. The stones around the pintle will be the same in both, as will be those in the sole, at the throat—excepting that in one of the latter the hinge and latch sockets will be omitted, as it will not be necessary to try the shutters in more than one case. Pintle and sole stones.

58. The inner portion of the sole may be formed of a thin flagging stone—the outer, of a flat inverted brick arch. The large wrought and cast-iron masses will be the same as in the granite embrasure. Of iron, there will be, in addition, a wrought-iron plate half an inch thick, bent around the small projecting portion of the cheek immediately in front of the throat, and kept in place, partly by two wrought-iron anchors strongly riveted to the front face; the sill-stone beneath must be cut away, so that the lower ends of these plates shall be about two inches below Sole. Additional irons.

Top. the sole. The embrasure at top will be closed by inner and outer brick arches.

59. It will be necessary to prepare this embrasure for a gun with the same accuracy as the granite embrasure, and lay behind it the traverse circles; for we must try the effect of the blast of the gun in this case also.

Traverse circles.

Precautions to be taken. 60. Considering what is said above as sufficient in reference to the general construction of the embrasure, I proceed to the particular precautions to be taken in laying the brickwork.

Embrasure of Charleston bricks. 61. In order that our test may have special results as regards bricks made in the southern part of the coast, where they have no stone of quality suitable for such uses, I have directed a sufficient number of good bricks to be sent to you from Charleston; and it is with these Charleston bricks that I desire the embrasure to be built.

Bricks unsightly, but durable. 62. The best bricks of that market are very unsightly, and cannot be made into a handsome wall; but they are very durable, standing the southern climate better than our northern brick. They are thought, moreover, to adhere strongly to mortar.

Arches. 63. The bricks used in the arches should not be cut into true voussoirs, but must fit their places by thin joints next the centre, and thicker at the extrados. It will not be necessary to bestow any particular pains on the appearance of the brick facing; but I wish every brick to be laid with the greatest care, as respects its connection with the mortar of the joints.

Great care in laying bricks.

Separation of bricks from mortar in previous firings. 64. In the late firings against brickwork, from a 42 pdr., it was noticed that there was a separation of bricks from mortar very generally, as the limit to the breach caused by the shot; and it was certain that if the cohesion had been greater, the effect of the shot would have been materially less. This brickwork had

nevertheless been laid under the direction of an experienced and very attentive officer—the bricks, though brittle, were hard, and the mortar was composed of cement and sand, without lime.

65. The want of cohesion was due, as seemed to me, beyond any doubt, to the interposition of dust, sometimes quite free, but perhaps more generally composing a layer slightly cohering to the body of the bricks. The process of laying must be to cause every brick to be thoroughly soaked in water, and to be laid the *moment it ceases to drip;* arrangements easily devised, will enable this to be done without extra expense: but I must caution you, that as this will be in some respects a disagreeable process to the masons, they will neglect it, or do it improperly, unless it be imperatively and perseveringly insisted on.

Cause of separation.

Process of laying bricks.

66. In order in some degree to compensate for the short time we are able to allow the new brick masonry to harden, I think the mortar to be used in the whole of the brickwork, including the brick embrasure, should be of dry cement two measures, to sand one measure. In other respects the mortar, concrete, &c. to be as directed in my letter of May 5th.

Composition of mortar.

67. Keep all masonry in progress shaded from the sun.

Masonry to be shaded.

68. I send also with this letter plans, sections and elevations of an embrasure to be faced exteriorly with concrete.

Plans, &c., of concrete embrasure sent. See Plate III., embrasure No. 9.

69. To form the iron throat of this embrasure, I wish you to have the wrought-iron masses (eight inches thick) that were used in old Embrasure No. 3 repaired, leaving off the shutters. The lower ends of these masses will be received in the granite stones of the sills, and the upper ends built in the arches. The throat being a little wider than before, the masses of

Throat.

the two sides will not unite at top or bottom; but this, for our present purpose, is of no consequence.

Wrought-iron plate.

70. This embrasure is to have the same half inch wrought-iron plate enveloping the first projection outside the throat as the brick embrasure; to be secured in like manner.

Pintle-stones, &c.

71. Portions of this embrasure—the pintle stones, tongue holes, sill stones, inside cheeks, sill and arch—will be the same as in the brick embrasure, only the outer facing being of concrete.

Concrete facing.

72. The concrete *used in the facing of this embrasure* should be made of mortar composed of cement two measures, sand one measure—the quantity of mortar to be twice the bulk of the void space in the brick fragments, reduced to a minimum nearly, by the admixture of fragments of bricks of different sizes, from that of a duck-shot to that of a pigeon's egg, all finer particles being sifted out.

Concrete backing.

73. The concrete backing *generally* may contain coarse fragments, broken stones, or broken bricks, or clean gravel, or all or any of these mixed, from the size of six or eight cubic inches down to the size of a hazelnut or less—clear, however, of all sand or dust.

Mortar.

74. All the mortar made for this target, whether to be used in concrete or not, should be made by first mixing well together, upon a floor, a small quantity of dry cement and the due proportion of sand; then quickly adding the necessary water at the moment it is about to be used, whether in concrete or masonry. Concrete should have the mortar added to the stone fragments as soon as it is made, and just as the concrete is to be applied. In other words, the first setting of the cement, which when it is energetic and good is very prompt, should not happen, even partially, until it is in place, and not liable to further disturbance. If this practice cannot always be accurately

followed, it should always be aimed at, and adhered to, as far as practicable.

Smearing surfaces with mortar.

75. Some of the mortar used in the concrete (somewhat diluted perhaps) should be smeared over the surface with which the concrete is to be in contact, the concrete being rammed in before this stucco has hardened: this is especially necessary on the sides of wooden moulds—which, moreover, if they have not been painted, should be made very wet.

To be shaded and kept moist.

76. While the concrete embrasure is under construction it should be kept shaded, and as soon as it is finished, should be stuffed full of wet grass or hay, and then a thickness of the same applied to the vertical surface—all being kept wet, the longer the better.

Facing concrete portion.

77. From the centre of the concrete embrasure No. 9 to the end of the target, ten feet, the facing should be of concrete, the corner being protected by brick blocking.

Facing.

Northern brick portion.

78. From the centre of the same, for a distance of thirteen feet towards the brick embrasure (No. 8), the facing will be of good northern bricks (avoiding the very brittle kind used in the old target), as will be all the brickwork in connection with the concrete embrasure.

Facing.

Southern brick portion.

79. For a distance of seven feet on one side and ten feet on the other of the brick embrasure (No. 8), the facings will be of Charleston bricks, as well as all the other brickwork of the embrasure.

Facing.

Granite portion.

80. Embrasure No. 7 will be faced for ten feet on each side with granite.

Refer to former letter.

81. A former letter refers to the manner of facing the interior of the target.

Cover over target.

82. A light wooden cover should be put on the top of the target to keep out rain.

Use no delay.

83. It is important that this target be made ready for the proposed tests as soon as practicable.

I am, very respectfully, sir,

Your ob't serv't,

(Signed) JOS. G. TOTTEN,
Bvt. Brig.-Gen. and Col. Eng'rs.

Interior facing of wall.

84. The interior facing of the wall was rubble-work, stones rather small.

Heart of wall.

85. The heart was of cement-concrete (without lime) composed of gravel and broken fragments of northern bricks and of stone, varying in size from pieces containing six or eight cubic inches down to that of a pea, sifted clear of sand and dust. The amount of mortar in this concrete was equal to twice the volume of void space in the mixed fragments, and was composed of cement measured in powder, and sand, in equal parts. All the mortar of the target was mixed with these proportions of cement and sand, except for the stone, brick, and concrete work, composing the embrasures themselves, which contained cement in paste *two* to sand *one*. The amount of this mortar in the fine concrete for Embrasure No. 9, was equal to twice the volume of void space in the broken fragments—the fragments being well soaked in a cream of cement immediately before mixing. To the left of the axis of No. 8, the fragments in the concrete composing the heart of the wall were soaked in a similar manner. One-half of the northern bricks and a like proportion of the southern were dipped in a cream of cement just at the moment of laying. In the wall, the portions of the two kinds of brickwork thus treated join each other.

SECTION V.

Tables from 8 to 16 inclusive, of firings from and against the Embrasures of 2d Target.

TABLE No. 8.

FIRING FROM 2D TARGET, THROUGH EMBRASURES NOS. 7, 8, AND 9, TO TEST THE EFFECT OF THE BLAST OF THE GUN UPON THE EMBRASURES.

Gun 8 inch Columbiad, length 10′ 4″, weight 9,240 lbs. | Casemate carriage.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Depression.	Direction.	REMARKS—July 18, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	degrees		
								From Embrasure No. 7.
89	8	10	ball	68	0	0	Direct	No effect on the embrasure. One shutter remained about half open. The ball did not pass through the bank of earth 24 feet thick, situated about 10 feet from the muzzle of the piece.
90	8	10	ball	68	0	0	Direct	No effect on the embrasure. One shutter remained about half open same as before, the other closed only one or two inches. Ball did not pass through the bank of earth.
91	8	10	ball	68	0	0	Trail traversed 30° to left	No effect on the embrasure. The right shutter closed and caught, the other closed one or two inches.
92	8	10	ball	68	0	0	Do.	No effect on the embrasure. The right shutter closed 6 or 8 inches, the other 1 or 2 inches.
93	8	10	ball	68	5	—	Do.	Same as before.
94	8	10	ball	68	—	3	Do.	No effect on the embrasure. The latch on the right shutter was strained by the blast, and would not work until the bolts had been loosened and oiled.
95	8	10	ball	68	—	3	Do.	No effect on the embrasure. Effect on the latch same as before, *i. e.*, pinched by bending of the lower bolt. A few blows on the side of the bolt set it right.
								From Embrasure No. 8.
96	8	10	ball	68	0	0	Do.	No effect on the embrasure.
97	8	10	ball	68	0	0	Do.	Do. do.

TABLE No. 8—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Depression.	Direction.	REMARKS—July 18, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	degrees		
98	8	10	ball	68	5	—	Trail traversed 30° to left	No effect on the embrasure.
99	8	10	ball	68	—	4	Do.	Do. do.
100	8	10	ball	68	—	4	Do.	Do. do.
101	8	10	ball	68	0	0	Trail 30° to right.	*From Embrasure No. 9.* A small piece of concrete on the outer edge of embrasure (about 4″ long, and 1½″ broad, and ½″ thick) was thrown off. No other effects. The piece appeared to be loose, as the break occurred where two layers of concrete joined.
102	8	10	ball	68	—	3	Do.	No effect on the embrasure.
103	8	10	ball	68	—	3	Do.	A very small piece of concrete was blown off, about 1″ high, and 1″ broad, and ½″ thick.
104	8	10	ball	68	6	—	Trail 30° to left	Two small pieces were blown off, one of them about 2″ high, and 1″ broad, and ½″ thick, the other about ½″ high, ½″ broad, and ½″ thick.
								NOTE.—The mean penetration of fourteen solid shots (weight 68 lbs., charge of powder 10 lbs.) into a recent mound of clayey soil, not very solidly compacted, distant 10 feet from the muzzle, was 12 feet 9 inches.

TABLE No. 9.

FIRING AGAINST 2D TARGET WITH CANISTER SHOT WEIGHING 1½ LBS. EACH.

Gun 42 pdr., length 10′ 9″, weight 8,465 lbs.
Platform level with bottom of target.
Axis of gun 4 feet above platform.

Total weight of canister 48 lbs.
Number of shot in canister 27.
Mean diameter of each shot 2¼ inches.

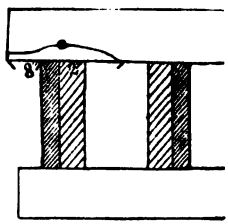
Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 23, 1855.
No.	lbs.		kind	lbs.	degrees	yds.	at	
105	42	⅛	Can'r.	48	¾	200	No. 7	Twelve shots struck the target. One of them struck and broke off the horizontal portion of the latch of the left-hand shutter, and then glanced and passed through the embrasure and screen. Two of them struck the southern brick wall, crater 4″ to 6″ ex. dia., and 2½″ to 3″ deep. One struck the lintel of the granite embrasure 6″ above the lower edge; cracked as per sketch. Fig. A. 
106	42	⅛	Can'r.	48	¾	200	No. 7	Eight shots struck the target. One struck the offset of left-hand shutter No. 7, and was stopped, making a slight indentation, say ¼″ deep, and 1¾″ broad. This shot was broken. The shutter which was struck was slightly disabled so as not to close, caused by opening the joint between the cylindrical strip attached to the inner edge and the body of the shutter. Had the three ½″ plates of the shutter terminated in this semi-cylinder, as the design contemplated, no additional strip would have been necessary, *no vertical cross joint would have existed there*, and consequently no injury would have been sustained by the shutter.

TABLE No. 9—*Continued.*

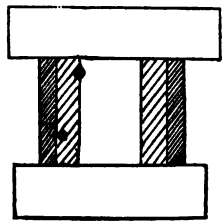
Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 23, 1855.
No.	lbs.		kind	lbs.	degrees	yds.	at	
107	42	$\frac{1}{8}$	Can'r.	48	$\frac{3}{4}$	200	No. 7	Four shots struck the target. One of them struck the left-hand throat piece of No. 7, $1\frac{1}{2}''$ from the edge, and broke in pieces, some of which passed through the embrasure and screen. Another struck the lintel about 2″ from the lower edge, throwing several pieces of stone through the embrasure and screen. In the screen were three holes and several indentations, some of stone and some of iron, scattered over an area of 4 or 5 feet square. Indentation in throat piece 2″ dia. and $\frac{1}{4}''$ deep.
108	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 7	Nine shots struck the target. All in granite or brick. No effect needing any particular description.
109	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 7	Seventeen shots struck the target, and one passed through No. 7 without touching. Penetration in granite little or nothing. Penetration in southern brick $3\frac{1}{2}''$ to 4″.
110	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 7	Six shots struck the target, and one passed through No. 7 without touching.
111	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 7	Eight shots struck the target all in the granite, and one passed through Embrasure No. 7 without touching.
112	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 7	Fourteen shots struck the target, all in the granite or brickwork.
113	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 7	Thirteen shots struck the target, and one passed through No. 7 without touching. One struck the edge of the left throat piece, No. 7, lapping about $\frac{1}{4}$ the dia., broke in two and passed through the screen. There was also an indentation in the screen from a fragment of the throat piece. Fig. B. 

TABLE No. 9.—*Continued.*

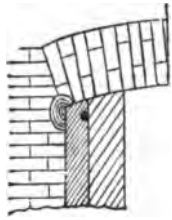
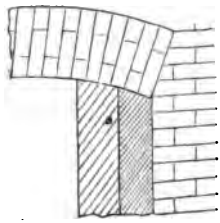
Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 23, 1855.
No.	lbs.		kind	lbs.	degrees	yds.	at	
114	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 7	Seventeen shots struck the target. One of them struck the offset of the left-hand shutter, indentation $1\frac{3}{4}''$ dia. by $\frac{1}{2}''$ deep. (See Fig. B.)
115	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 8	Seven shots struck the target. One struck the left outer edge of No. 8 at the spring of the arch, took out a piece of brickwork about 5″ by 4″ by 3″, glanced to the boiler iron of the offset, making an indentation about $1\frac{1}{2}''$ dia., by $\frac{1}{4}''$ deep. It was broken and stopped. Fig. C.  One in the concrete wall to left, crater 10″ dia., and $3\frac{3}{4}''$ deep.
116	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 8	Fourteen shots struck the target. One of them struck against the right throat piece of No. 8, about 8″ from the top; indentation $1\frac{1}{2}''$ dia. by $\frac{1}{4}''$. Stopped and broken. Fig. D. 
117	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 8	Twelve shots struck the target, all in the granite or brick. No particular effects. Penetration of these canister shots in northern brick $2\frac{1}{2}''$ to $2\frac{3}{4}''$. Ex. dia. of crater 6″ to 8″.

TABLE No. 9—*Continued.*

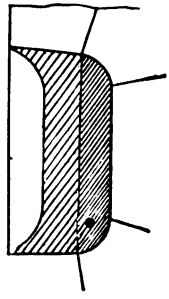
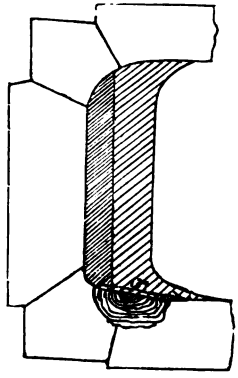
Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 23, 1855.
No.	lbs.		kind	lbs.	degrees	yds.	at	
118	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 8	Thirteen shots struck the target, all in the granite or brick. No particular effects. Penetration of these canister shots into southern brick is somewhat greater, say about $\frac{1}{2}''$, than in the northern brick; the exterior diameter of crater about the same.
119	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 9	Fifteen shots struck the target, and 1 passed through No. 9 without touching. One of the 15 struck the boiler plate of the right offset of No. 9, indentation $1\frac{1}{2}''$ dia., by $\frac{3}{4}''$ deep, and stopped. The crater in concrete by these canister shot averages about 9″ to 10″ exterior diameter, by 3″ deep. Fig. E. 
120	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 9	Thirteen shots struck the target. One of them struck the sill of No. 9, a Fig. F.  few inches below the sole, knocking out a piece of concrete 13″ by 7″ by 8″. Nothing went through.

TABLE No. 9—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 23, 1855.
No.	lbs.		kind	lbs.	degrees	yds.	at	
121	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 9	Thirteen shots struck the target; none of them very near the embrasure, except one on the sill of the outside of the embrasure No. 9, increasing a previous fracture.
122	42	$\frac{1}{8}$	Can'r.	48	$\frac{1}{2}$	200	No. 9	Fourteen shots struck the target; one on the lintel of the left outer edge of No. 9, making a fracture 10″ on the edge, and extending 8″ inwards on the intrados, and about the same distance up the wall on the outer face. One shot struck the left throat piece full centre, 2″ from the inner edge, indentation 2″ in diameter and $\frac{1}{2}$″ deep. This shot was stopped and broken.

Fig. G.

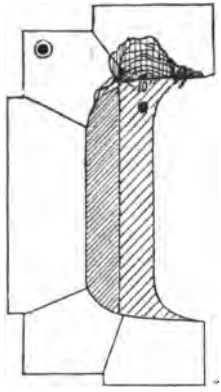


TABLE No. 10.

FIRINGS AT 2D TARGET WITH CANISTER SHOT OF $\frac{43}{100}$ OF A POUND EACH, 6.88 OZ.

Gun 42 pdr., length 10′ 9″, weight 8,465 lbs.
Platform level with bottom of target.
Axis of gun 4 feet above platform.

Total weight of canister 51¼ lbs.
No. of shot in each canister 80.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 23, 1855.
No.	lbs.		kind	lbs.	degrees	yds.	at	
123	42	⅛	Can'r.	51¼	¾	200	No. 9	Thirty-one shots struck the target. One inside of No. 8 on left hand offset; indentation 1″ dia. by ¼″ deep. Crater in northern brickwork about 3″ ext'r dia., by 2″ deep: in Charleston brick, penetration about ¼″ greater. Craters in concrete, 3″ to 5″ ext'r dia., and ¾″ to 1¼″ deep.
124	42	⅛	Can'r.	51¼	¾	200	No. 8	Three hundred and thirty-five shots struck the target (stone, brick, and concrete). One struck left-hand throat piece of No. 9, about 9″ from the top. Shot broke, and was stopped. One passed through No. 9 without touching. Seven struck offsets in No. 8, and were stopped. One struck edge of sill, glanced up to the edge of the left throat piece, and thence to the screen, without breaking. It did not pass through the screen. And one struck the edge of the right throat piece, and glanced through the screen. Six shots passed through No. 8 without touching. One of the shots against the throat piece of No. 8 struck about 5″ from a bolt head, and broke the latter off. One shot struck the left throat piece of No. 7, and was stopped; and four passed through without touching.
125	42	⅛	Can'r.	51¼	¾	200	No. 8	
126	42	⅛	Can'r.	51¼	¾	200	No. 8	
127	42	⅛	Can'r.	51¼	¾	200	No. 8	
128	42	⅛	Can'r.	51¼	¾	200	No. 8	
129	42	⅛	Can'r.	51¼	¾	200	No. 8	
130	42	⅛	Can'r.	51¼	¾	200	No. 8	
131	42	⅛	Can'r.	51¼	¾	200	No. 8	
132	42	⅛	Can'r.	51¼	¾	200	No. 8	
133	42	⅛	Can'r.	51¼	¾	200	No. 8	
134	42	⅛	Can'r.	51¼	¾	200	No. 8	One shot passed through No. 9 without touching; none struck the iron work. Seven struck offsets in No. 8 full, and were stopped. One struck the edge of the right throat plate, and glanced through the screen. Six passed through without touching, and one struck the screen without passing through it; one fragment remained in the
135	42	⅛	Can'r.	51¼	¾	200	No. 8	
136	42	⅛	Can'r.	51¼	¾	200	No. 8	
137	42	⅛	Can'r.	51¼	¾	200	No. 8	
138	42	⅛	Can'r.	51¼	¾	200	No. 8	
139	42	⅛	Can'r.	51¼	¾	200	No. 8	
140	42	⅛	Can'r.	51¼	¾	200	No. 8	
141	42	⅛	Can'r.	51¼	¾	200	No. 8	
142	42	⅛	Can'r.	51¼	¾	200	No. 8	

TABLE No. 10—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 23, 1855.
No.	lbs.		kind	lbs.	degrees	yds.	at	
								screen. Three shots struck the offsets in No. 7, and were stopped; and one passed through without touching. Two fragments struck the screen, and entered about half an inch. One shot struck the left outer edge of granite embrasure, knocked off a piece about 8″ high by 1½″ wide, and extending in as far as the recess for the shutter.

TABLE No. 11.

FIRINGS AT 2D TARGET WITH MUSKET BALLS IN CANISTERS.

Gun 8 inch Columbiad, length 10′ 4″, weight 9,240 lbs.
Platform level with bottom of target.
Axis of gun four feet above platform.

Total weight of canister 82 lbs.
Number of balls in each canister 1188.
Balls of lead 18 to the pound.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 24, 1855.
No.	inch.		kind	lbs.	degrees	yds.	at	
143	8	⅛	Can'r.	82	¼	200	No. 8	One musket ball stopped by offsets No. 9; two passed through No. 9 without touching, into the screen. Five balls stopped by offsets of No. 8, and four passed through No. 8 without touching, and through the screen. No. 7 was not struck; but one passed through without touching, and through the screen.
144	8	⅛	Can'r.	82	¼	200	No. 8	Two balls stopped by offsets of No. 9, and one passed through without touching, and through the screen. Eight struck offsets of No. 8, and were stopped; and thirteen passed through No. 8 without touching, and through the screen. One struck offset of No. 7, and was stopped; and one passed through without touching, and through the screen.
145	8	⅛	Can'r.	82	¼	200	No. 8	One ball struck offset of No. 7, and was stopped. None passed through. Eleven struck offsets in No. 8, and were stopped; and six passed through without touching, and through the screen. One struck offsets of No. 9, and was stopped. None passed through.
146	8	⅛	Can'r.	82	¼	200	No. 8	Nine balls struck offsets of No. 8, and were stopped; and 9 passed through without touching, and through the screen. One struck the sole of No. 7, and glanced to offset on shutter, and was stopped. Two passed through No. 7 without touching, and through the screen.
147	8	⅛	Can'r.	82	½	200	No. 8	One ball through No. 9 without touching, and through screen. None touched the iron work. Several struck the concrete, but made scarcely any impression on it. Six struck

TABLE No. 11—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 24, 1855.
No.	inch.		kind	lbs.	degrees	yds.	at	
								the offsets of No. 8, and were stopped; and four passed through without touching, and through the screen. The balls made little or no impression on the northern brick. One shot struck offsets of No. 7, and was stopped. None passed through.
148	8	⅛	Can'r.	82	½	200	No. 8	One passed through No. 9 without touching. None hit the iron work. Ten struck offsets of No. 8, and were stopped, and eight passed through without touching, and through the screen. Two struck offsets of No. 7, and were stopped. None passed through.
149	8	⅛	Can'r.	82	½	200	No. 8	One ball passed through No. 9 without touching. None hit the embrasure. Three balls struck offsets of No. 8, and were stopped, and two passed through without touching. One through No. 7 without touching, and one by deflection.
150	8	⅛	Can'r.	82	½	200	No. 8	One through No. 7 without touching. None hit the embrasure. Eight struck offsets of No. 8, and were stopped; and eight passed through without touching, and through the screen. One struck offsets of No. 9, and was stopped. None passed through.
151	8	⅛	Can'r.	82	½	200	No. 8	One struck offsets of No. 9 and stopped, and two passed through without touching, and through the screen. Six struck offsets of No. 8 and were stopped, and four passed through without touching, and through the screen. Two passed through No. 7 without touching.
152	8	⅛	Can'r.	82	½	200	No. 8	The iron work of No. 7 was not touched, and no marks were upon the screen behind it. Three struck offsets of No. 8, and were stopped, and two passed through without touching, and through the screen. One struck offsets of No. 9 and stopped, and one passed through without touching, and through the screen.

TABLE No. 11—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 24, 1855.
No.	inch.		kind	lbs.	degrees	yds.	at	
153	8	$\frac{1}{8}$	Can'r.	82	$\frac{1}{2}$	200	No. 8	None struck iron work of No. 9, and no marks upon the screen behind it. Seven struck No. 8 and were stopped, and four went through without touching, and through the screen. None struck No. 7, and none went through.
154	8	$\frac{1}{8}$	Can'r.	82	$\frac{1}{2}$	200	No. 8	Two shots struck offsets of No. 7, and were stopped, and 4 passed through without touching, and through the screen. A part of the bottom of the canister also passed through No. 7, and stuck in the screen. Seven shots struck offsets of No. 8, and were stopped; and six went through without touching No. 8, and through the screen. Two went through No. 9 without touching.
155	8	$\frac{1}{8}$	Can'r.	82	$\frac{1}{2}$	200	No. 8	One shot struck offsets of No. 9, and was stopped, and one went through without touching, and through the screen. Thirteen shots struck offsets of No. 8, and were stopped; and four went through without touching, and through the screen. None struck or went through No. 7.
156	8	$\frac{1}{8}$	Can'r.	82	$\frac{1}{2}$	200	No. 8	Three shots struck offsets of No. 7, and were stopped; and four passed through without touching, and through the screen. Sixteen shots struck offsets of No. 8, and were stopped; and ten passed through without touching, and through the screen. One shot struck offsets of No. 9, and stopped. None passed through No. 9.
157	8	$\frac{1}{8}$	Can'r.	82	$\frac{1}{2}$	200	No. 8	Two shots struck offsets of No. 9, and were stopped. None passed through. Ten shots struck offsets of No. 8, and were stopped; and 9 passed through without touching, and through the screen. Two shots struck offsets of No. 7, and were stopped; and three passed through No. 7 without touching, and through the screen.

TABLE No. 12.

FIRING AT 2D TARGET WITH IRON CANISTER SHOT OF $\frac{21}{100}$ OF A POUND EACH, ABOUT $3\frac{1}{3}$ OZ.

Gun 8 inch Columbiad, length 10′ 4″, weight 9,240 lbs.
Platform level with bottom of target.
Axis of gun 4 feet above platform.

Total weight of canister 55 lbs.
Number of balls in each canister 222.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 24, 1855.
No.	inch.		kind	lbs.	degrees	yds.	at	
158	8	$\frac{1}{8}$	Can'r.	55	$\frac{1}{2}$	200	No. 7	Two shots struck the right throat plate, and one the left throat plate of No. 7, and were stopped. Indentation 1″ dia. and $\frac{1}{2}$″ deep; one shot struck the upper edge of the sill, glanced to the edge of the shutter, and stopped. None passed through.
159	8	$\frac{1}{8}$	Can'r.	55	$\frac{1}{2}$	200	No. 7	Five shots struck offsets of No. 7, full, and were stopped. One shot struck the edge of the sill of No. 7, glanced to the edge of the throat plate, and thence through the screen towards the left.
160	8	$\frac{1}{8}$	Can'r.	55	$\frac{1}{2}$	200	No. 7	One shot struck offset of the right shutter of No. 7, and stopped; and one struck the shoulder of the shutter, and glanced through the embrasure into the screen, but not through it.
161	8	$\frac{1}{8}$	Can'r.	55	$\frac{1}{2}$	200	No. 7	A piece of the canister passed through No. 9, into the screen, but not through it. One shot struck the right throat plate of No. 7, and stopped; and one struck the side of the right shutter, glanced to the throat plate, and stopped. One shot struck the lintel of No. 7 about 4″ above the lower edge and broke off a piece 4″ by 15″ long and 4″ deep. The shot was found in the embrasure.

Fig. H.

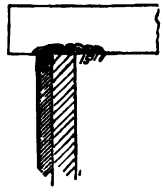


TABLE No. 12—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 24, 1855.
No.	inch.		kind	lbs.	degrees	yds.	at	
162	8	⅛	Can'r.	55	½	200	No. 7	One shot struck the lintel, and glanced through the embrasure, and through the screen. One glanced from the lintel, and was stopped by the offsets of the shutter.
163	8	⅛	Can'r.	55	½	200	No. 7	Three shots struck offsets of No. 7, and were stopped. Fig. I. One shot struck the edge of the right shutter, and glanced through the embrasure; and through the screen. Three passed through the embrasure without touching, and through the screen.
164	8	⅛	Can'r.	55	½	200	No. 7	One shot struck offset of No. 8, and stopped. None passed through. Four shots struck offsets of No. 7, and were stopped. One struck the shoulder of the shutter, broke, and the fragments went through the embrasure.
165	8	⅛	Can'r.	55	½	200	No. 7	Two shots struck offsets of No. 7 full, and stopped, and two passed through without touching, and through the screen.
166	8	⅛	Can'r.	55	½	200	No. 7	Two shots struck offsets of No. 7 full, and were stopped; and one passed through without touching, and through the screen. One shot struck the right outer edge of No. 7, 1′ from the edge, and broke off a piece 1″ by 6″, and stopped.

Fig. I.

Fig. J.

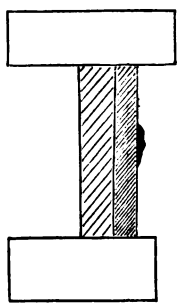


TABLE No. 12—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 24, 1855.
No.	inch.		kind	lbs.	degrees	yds.	at	
167	8	⅛	Can'r.	55	½	200	No. 7	Five balls struck offsets of No. 7 full, and stopped; and three passed through without touching, and through the screen. One shot struck the left outer edge 2″ from the edge, and broke off a piece 2″ by 4″ by 3″.
168	8	⅛	Can'r.	55	½	200	No. 7	Two shots struck offsets of No. 7 full, and were stopped. One went through the embrasure without touching, and through the screen. One shot struck the sill of No. 7, about 2″ below the upper edge, and cracked it 3″ by 4″ in each direction.
169	8	⅛	Can'r.	55	½	200	No. 7	Five balls struck offsets of No. 7 full, and stopped, and one went through without touching, and through the screen. One struck the upper edge of the sill, and glanced through the embrasure and screen.
170	8	⅛	Can'r.	55	½	200	No. 7	Two balls struck offsets of No. 7, and were stopped; and three passed through without touching, and through the screen. One ball struck the edge of the right throat piece, glanced to the opposite cheek, and through the screen.
171	8	⅛	Can'r.	55	½	200	No. 7	Five balls struck offsets of No. 7, and were stopped; and eight passed through the embrasure and screen.
172	8	⅛	Can'r.	55	½	200	No. 7	Two balls struck offsets of No. 7, and stopped, and one passed through the embrasure by glancing (probably by ricochet). One struck the left outer edge, knocking off a small piece of granite, say 1″ by 1″ by 1″, and glanced through the embrasure and screen.
173	8	⅛	Can'r.	55	½	200	No. 7	Two balls struck offsets of No. 8, and stopped, and one passed through the embrasure and screen. One struck the screen (probably by ricochet), but did not go through. Two passed through No. 7 without touching.
174	8	⅛	Can'r.	55	½	200	No. 7	Two shots struck offsets of No. 7, and stopped, and two went through without touching, and through the screen. One struck the granite sill 2″ below

TABLE No. 12—*Continued.*

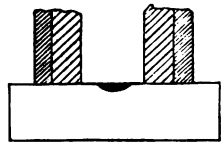
Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 24, 1855.
No.	inch.		kind	lbs.	degrees	yds.	at	
								the edge and knocked off a piece 3″ by 6″ by 3″; ball stopped. Fig. K. 
175	8	1/8	Can'r.	55	1/2	200	No. 7	One shot struck offsets of No. 7, and stopped, and two passed through without touching, and through the screen. One struck the shoulder of the left shutter, glanced to the opposite inner cheek, and then through the screen.
176	8	1/8	Can'r.	55	1/2	200	No. 7	One shot struck offsets of No. 8, and stopped; three struck offsets of No. 7, and stopped, and one struck on the joint between the latch and shutter, so far disabling the latch as to render it unserviceable, for a time at least. Fig. L.
177	8	1/8	Can'r.	55	1/2	200	No. 7	Three shots struck offsets of No. 7, and stopped, and one struck the upper edge of the horizontal portion of the latch of the right shutter, broke and glanced to the offsets of the shutters and stopped. None passed through.
								NOTE.—On the outer face of the wall around No. 7, a rectangle 4′ by 5′ was traced, to represent the exterior opening of an old form of embrasures; between this outline and the exterior opening of No. 7 (new form), 111 shots struck in the course of the firing at the 2d target. In the old size and form of embrasures, all these shots would have entered the casemate.

TABLE No. 13.

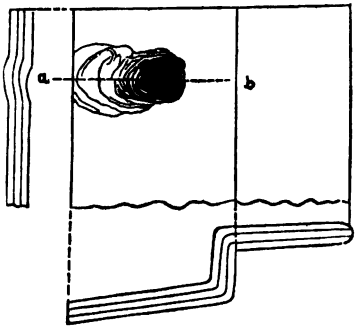
FIRING AGAINST 2D TARGET WITH GRAPE SHOT, EACH SHOT WEIGHING 4 $\frac{2}{10}$ LBS.

Gun 8 inch Columbiad, length 10′ 4″, weight 9,240 lbs.
Platform level with bottom of target.
Axis of gun 4 ft. above platform.

Total weight of stand of grape 51¼ lbs.
Number of shot in each stand 9.
Diam. of each shot 3.17 inches.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 24, 1555.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
178	8	6½	Grape	51¼	½	200	No. 7	One shot struck the target in the granite. Penetration about ½″.
179	8	6½	Grape	51¼	½	200	No. 7	One shot struck the right outer edge of No. 8 about 4″ from the edge; cut through the brick, and was stopped by the shoulder of offset which was covered with a plate of ½ inch boiler iron, doing no damage to the plate which it impressed about ¼ of an inch. One shot struck the granite.
180	8	6½	Grape	51¼	½	200	No. 7	One shot struck the right shutter of No. 7, 4″ from the top and 5½ inches from the edge, indentation about 4″ dia. and ⅜″ deep. The diameter of the part touched by ball about 2″. The lower bolt head of the latch was considerably broken off, and the bolt somewhat started in. The shutter was slightly bent, behind the part where the shot struck, but not damaged. The other shutter, for want of a latch, was thrown partly open. The shot was broken. One piece, about one-third of the shot, was found on the inside, but it left no mark on the screen.

Fig. M.
Top of Shutter.



Horizontal Section on *a b*.

TABLE No. 14.

FIRING AGAINST 2D TARGET WITH SOLID SHOT OF 24 LBS. WEIGHT.

Gun 24 pdr., length 10′ 4″, weight 5,790 lbs.
Platform level with bottom of target.
Axis of gun 4′ 3″ above platform.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 24, 25, 26, 1855.
No.	lbs.		kind	lbs.	degrees	yds.	at	
181	24	¼	Ball	24	½	200	Mark on concrete between No. 9 and end of target	Shot was lost.
182	24	¼	Ball	24	½	200	Do.	Shot struck about 1 foot above the left end of the lintel of No. 9. Penetration 1′ 10″. Exterior diameter of crater about 3′ 6″, extending to the top of the wall, where it was 4′ 6″, and cracked the wall entirely through, and extending to the end of the wall on the left. Ball did not break. For point struck see Fig. N.
183	24	¼	Ball	24	½	200	Do.	Shot struck to the left of the lintel of No. 9, about 1′ 9½″. Penetration 1′ 3½″. Exterior diameter of crater 2′ 6″. Cracked the concrete horizontally to the end of the wall. For point struck see Fig. N.
184	24	¼	Ball	24	½	200	Do.	Shot struck on the sill about 10″ from the edge, on a line with the edge of the left side produced—penetration 10″, the shot having struck the outer

Fig. N.

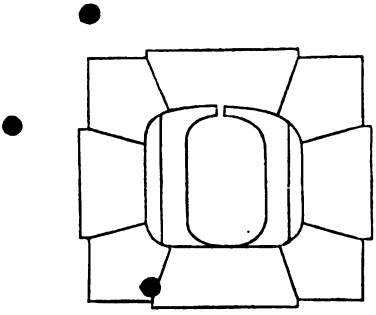


TABLE No. 14—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 24, 25, 26, 1855.
No.	lbs.		kind	lbs.	degrees	yds.	at	
								sill stone—cracking the sill through to the inner face of the wall, through both of the inner sill stones, without displacing either, or the iron offset—the crack being a slight one. The ball was broken. The action of the ball seems to have been communicated directly to the left throat plate; thence to the inner sill stones, cracking the first one in a slight crack directly to the rear, and loosening the joint of the sill stone with the cheek of the embrasure. The rear sill stones were cracked directly to the rear, a continuation of the crack through the first; this stone was loosened in its bed, and at each end cracked from the cheeks. The crack at the left end continued down some 18″ between the brickwork and the end of the stone under the sill. At the other end the brickwork of the cheek was slightly cracked for about 12″, in a line inclining at an angle of 45° to the back of the wall. A slight disturbance of the mortar was visible in the joint between the brickwork, and the stone under the back sill, as at the other end. At the top, the shock on the cheek plate scaled off a small portion of the brickwork from the soffit of the arch. The embrasure as serviceable as ever apparently. For point struck see Fig. N.
185	24	¼	Ball	24	½	95	No. 9	Shot struck directly under the axis of the embrasure opposite the tongue hole, passed through, into, and through the tongue hole and under

Fig. O.

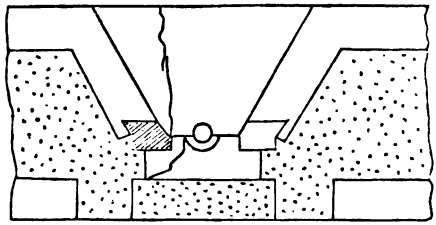


TABLE No. 14—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 24, 25, 26, 1855.
No.	lbs.		kind	lbs.	degrees	yds.	at	
								the screen. Carried away all the concrete in front of the outer sill, as low down as the point where the ball struck. Cracked the outer sill stone up and down directly through the centre, and horizontally towards the left, about 4″ below the top of the sill, as far as the crack caused by the previous shot. No additional derangement of the sill stone in the rear, or of the stones around the tongue hole. The ball in passing through the tongue hole, did not carry away any bricks, but broke off the corners of those on the inner edge. Embrasure still serviceable; although, had the casemate carriage been mounted, the pintle would probably have been broken.
186	24	¼	Ball	24	½	95	Left throat plate No. 9	Through without touching.
187	24	¼	Ball	24	½	95	Do.	Do. do. do.
188	24	¼	Ball	24	½	95	Do.	Passed through just grazing six of the ½″ plates of the right throat plate, and loosening the joint around the bottom of the throat plate, and cracking the outer sill from the outer face of the throat plate as far as the pintel hole; also cracked the concrete in the roof from the joint where the right offset enters the intrados to the outer face of the wall, extending diagonally up to the right, about 8″. Inner sill stones slightly shaken. Started the joint on the inside at junction of the cheek and soffit for about 2′ from the throat plate. Embrasure as serviceable as ever.
189	24	¼	Ball	24	¼	95	Left throat plate No. 9 at the middle.	Shot struck directly where it was aimed, grazing the boiler iron of the outer offset, penetration 2¼″; besides a general bending in of 1¼″ in addition, extending to the top and bottom of the plates. The ball broke, and about one-half of it remained in the crater, the other half broke into small pieces, but none entered the embrasure. The entire 8″ throat

TABLE No. 15.

FIRING AGAINST 2D TARGET WITH SOLID SHOT OF 68 POUNDS WEIGHT.

Gun 8 inch Columbiad, length 10′ 4″, weight 9,240 lbs.
Platform level with bottom of target.
Axis of gun 4 feet above platform.

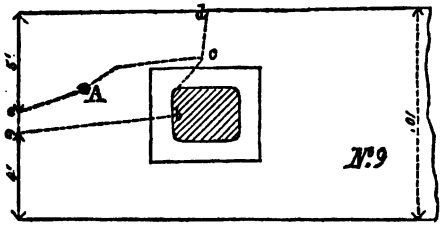
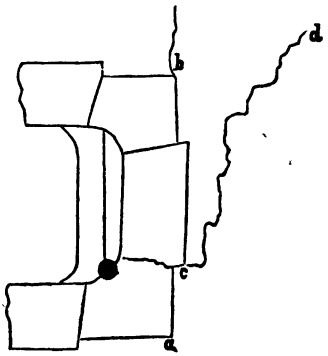
Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 26, 27, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
193	8	10¼	Ball	68	3/8	200	Between No. 9 and end of target	*A*, point struck. Penetration 2′ 2½″. All between the lines *a b* and *e A c* partially ruined. All outside the line *e A c d* ruined. Considerable portions knocked off, wall being much shaken by previous shots. The ball fell back whole. Fig. R. 
194	8	10¼	Ball	68	3/8	200	Right cheek, No. 9	Ball struck at the foot of the boiler plate, at the junction between it and the sill, penetration 1′ 9″. Fig. R′.  Ball stopped and broke to pieces. Line *a b* is right edge of the embrasure jamb. Crack along *a b* and along

TABLE No. 15—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 26 and 27, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
								c d to the top of the target. The shock cracked the rear sills entirely through, in direction of the shot. The right cheek was cracked obliquely from the bottom of the throat piece (right) to the top of the cheek to the rear. A large crack was made through the corner of the arch. Several bricks were torn out of the rear part of the right cheek by the shock from the sill stone. Several scaling cracks were made in the cheek behind the throat plate.
195	8	10½	Ball	68	⅜	200	Right cheek, No. 9	Ball struck the right jamb of No. 9, in the concrete near its junction with the brickwork, and about 10″ below the plane of the lower surface of the lintel. The ball passed through the wall, leaving evidences of having been slightly deflected to the left, as it approached the inner cheek, forced the throat plate completely from its position, throwing the upper end against the opposite side of the embrasure, and leaving it in the opening inclined at an angle of about 45°. The plate of boiler iron of the outer offset was thrown from its position to the front, out of the embrasure. The horizontal dimension of the embrasure at the throat was enlarged by this shot, and by those on the opposite cheek, to 4′ 10″. The brickwork to the right of the point where the ball struck was considerably carried away within a radius of about 1′ 9″ to 1′ 10″, and several cracks in the beds of the brickwork, extended 5′ to 5½′ to the right. Three large cracks also extended to the top of the wall obliquely to the right and left. The main effect of this discharge was caused by the ball passing entirely behind the throat plate, between it and the masonry, forcing the plate laterally from its position, as no support whatever was furnished by the opposite throat, it having been carried away by previous discharges. The plate was not touched by the ball or injured by the effects. All the brickwork of the inner cheek, except a part of the three lower cor-

TABLE No. 14—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 24, 25, 26, 1855.
No.	lbs.		kind	lbs.	degrees	yds.	at	
								plate was indented, and bent generally inwards from its true position about 1⅝″. The top and bottom remained in position, but at the top the joints around the plates were considerably deranged, and opened about ⅛″. Nearly all the sixteen ½″ plates composing the throat plate were cracked directly behind the crater, and two of the bolt heads were knocked off on the inner side. Directly behind the throat plate on the inner cheek, a wedge-shaped mass of brickwork 9″ wide at the top, and running to nothing at the sole, and extending towards the inner face from 9″ to 12″, was knocked off, and two cracks extended horizontally on the cheek from the throat plate to the inner face of the wall. The arch was just visibly cracked from the throat to the inner face along the string course directly behind the left throat plate. The skew-back joint on the same side showed a decided derangement, say ⅛″ on the inner face. The brickwork of the whole inner cheek was started inward about ¼ of an inch. No additional disturbance on the other side of the embrasure. Embrasure still serviceable.
190	24	¼	Ball	24	¼	95	Left cheek, No. 9	Ball struck 7⅜″ from the bottom of the extreme left iron offset plate, grazing edge of the concrete, struck iron about ½″ from the left perpendicular edge, depth of penetration 1′ 4″. Exterior diameter of indentation 8½″. Diameter of the hole made by the ball in entering 7″. Interior of cavity made by the ball 1′ 2″. The left side of this cavity was about 2″ from the concrete cheek. Ball struck the rear part of the offset plate, next the throat plate, and changed direction to the left. Rear plate broken in two. Inner face of the offset carried away. Ball carried before it a piece of the outside boiler plate. Ball bent the throat plate; broke off the bolt head, and fractured the outer edge of the first throat plate. Two bolts behind the ball bent downwards. Boiler plates separated from concrete in direction of the middle of the target. Fracture in the brickwork behind throat enlarged to 1′ 3″ in width along the cheek. All the

TABLE No. 14—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 24, 25, 26, 1855.
No.	lbs.		kind	lbs.	degrees	yds.	at	
								brickwork of this cheek driven in about half an inch; many of the bricks were broken, and several additional cracks up and down the cheek. The ball broke into fragments against the throat plate. No fragments thrown against the screen. Repairs might be soon made which would put the embrasure in serviceable condition.
191	24	¼	Ball	24	¼	95	Left cheek, No. 9	Ball struck the boiler plate just above the previous shot, passed through between the throat plates and brickwork; carried away all of the offset above the previous shot, and bent in the throat plates at the bottom. The bricks lining the interior of the embrasure, jarred out of place. An opening behind the throat plate, caused by the ball, from 3″ to 6″ wide, and extended from top to bottom. By removing the throat plate the embrasure will still be serviceable.
192	24	¼	Ball	24	¼	95	Left cheek, No. 9	Ball struck the throat plates just below the shot which struck in No. 189, carried the throat plate to the rear 20′. First eight plates thrown to the right, and the second eight to the left. All of the plates fractured. All of the bolts connecting the two sets of plates broken. Embrasure still serviceable.

Fig. P.

Edge view of the eight ½ inch plates, forming the outer half of the left throat piece of No. 9.

Fig. Q.

Edge view of the eight ½ inch plates, forming the inner half of the left throat piece of No. 9.

TABLE No. 15—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 26 and 27, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
								ners, was carried away, and the inner arch was cracked through and through, from the spring to the crown, and also along the joints of the lower string course. A part of the screen, about 7 feet square was carried away.
196	8	10¼	Ball	68	3/8	200	Left cheek, No. 8	The shot struck the left throat plate about 4½″ below the top, lapping on the throat plate about half the diameter of the ball, was deflected to the right, breaking out small segments from four of the plates, and bending the inner plate 1¾ inch. Penetration 4⅛ inches. It also broke off a wedge-shaped piece of cast iron 1′ high, 3″ thick, and 2¾″ to 4¼″ broad, measured towards the inner face. The cast iron was also cracked horizontally about 4″ below the roof of the em-

Fig. S.

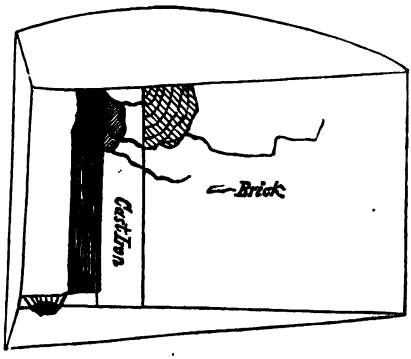


Fig. T.

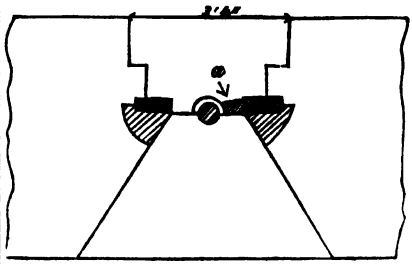


TABLE No. 15—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 26 and 27, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
								brasure. Two other small cracks were also made, but probably not through the mass. Behind the cast iron on the inner cheek a wedge-shaped mass of brickwork about 1′ high, 3″ thick, and 9″ broad, measured along the cheek, was broken off, and several minute cracks on the inner face, directly behind the iron work were distinctly visible. A crack was also made on the inner arch, along the ring courses, about 5″ from the inner face, extending from the springing line to within six inches of crown. No disturbance was visible on the inner face of the wall, nor bottom of inner cheeks. A small part of the arch 2″ thick, where the cast iron enters, was broken off. Also a small piece of the outer granite sill from pintle to throat plate, 6″ wide and 7″ deep; see *a*, Fig. T. Embrasure still serviceable.
197	8	10½	Ball	68	⅜	200	Left cheek, No. 8	The shot struck the upper part of the left outer offset, including a portion of the arch, passed through the offset, leaving the lower part in position, striking the throat plate about 6½″ from the upper end, 2½″ from the left edge; indented and penetrated this plate about 1⅝″. The ball was then deflected to the left, and passed through in fragments between the throat plate and masonry. The head of the arch where the ball struck was considerably carried away within an exterior radius of 1′ 6″. The cracks in the brickwork did not extend to any great distance from the crater (say 1′ to 15″). The top of the throat plate was forced in and to the right about 15 inches, and was left standing at an angle of about 75° with the horizon. By removing this plate, the embrasure will still be serviceable. The cast-iron backing was broken off about 1 foot above the sole of the embrasure, and the upper portion thrown to the rear in four pieces, about 15 feet. The inner arch was broken in two, from cheek to cheek, and its junction with the opposite cheek considerably dis-

TABLE No. 15—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 26 and 27, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
								turbed. A part of the head of the inner arch 4″ to 5″ thick, from the spring to the crown was carried away. The inner cheek behind the point where the ball struck was badly fractured in all directions. About ⅛ of the brickwork composing it was carried away entirely. The rest was forced inward from 2″ to 3″. On the inner face the cracks extended from the arch to the top of the wall, and horizontally 3′ from the fractured cheek. The sills remain entire and immovable, and the other cheek was not at all injured.
198	8	10¼	Ball	68	⅜	200	Left cheek, No. 8	Ball struck the throat plate that was left inclined before, and carried away this plate. No other effect.
199	8	10¼	Ball	68	⅜	200		The shot struck the boiler plate of the right outer offset, 2′ from the sill, even with the spring of the arch, and 3½″ from the outer edge of the plate. Disturbed the outer course of the brick, just underneath and to the right of the point struck, within a radius of about 2′ 2″. Also disturbed the two outer courses of brick above the crown of the arch. Cracks of small extent in the wall near the top, just over the point struck. Ball carried away the upper part of the boiler plate, also the whole of the throat plate. The latter fell about 1′ in rear of the embrasure. Cast-iron mass broken off 15″ above the sole; the upper part was carried to the left and rear, in two pieces, one 15′, the other 25′ from the embrasure. The cast-iron piece remaining in place was slightly inclined towards the centre of the embrasure; more than ¾ of the inner arch carried away. Brick facing to the thickness of half a brick, was carried away from the inner cheek. A slight disturbance between the inner and outer sill, caused by the latter being wedged outward by cast-iron pieces. The inner sill was not disturbed, except the vertical joints, which were very slightly cracked. Joints all slightly disturbed in the

TABLE No. 15—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 26 and 27, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
								stonework of the inner face above the arch, and extending to the top of the wall. Some cracks made before were enlarged, and some new ones caused in that facing. A small wedge-shaped piece of stone was broken from the outer sill at the throat, between the iron work and pintle hole. Embrasure serviceable, provided the remaining pieces of cast iron be removed.
200	8	10¼	Ball	68	⅜	200	Left of wall between No. 9 and the end	The ball struck 2′ above and 1′ to the left of the point aimed at, carrying away all the wall above the point struck, from the end of the wall to Embrasure No. 9.
201	8	10¼	Ball	68	⅜	200	Do.	Ball struck a little to the right of the mark, and 3″ or 4″ above.
202	8	10¼	Ball	68	⅜	200	Do.	Ball struck 1′ from the bull's eye, and to the right above. NOTE.—The last three shots were fired to get the elevation of the piece, preparatory to firing at the cheeks of No. 7.
203	8	10¼	Ball	68	¼	200	Centre No. 7	The shot struck the lintel about 4″ above the lower edge, and 5″ or 6″ to the left of the right outer edge; shattered the lintel in all directions, and disturbed the joints obliquely to the right and left, as far as the top of the wall. The ball was deflected downwards, and stopped, after penetrating as far as the offsets of the shutters, say 10″. It was broken in pieces (partially against the offsets of the shutters), two or three of which passed through the screen. The screen was not otherwise injured. The fracture in the lower portion of the lintel extended in as far as the throat, and towards the left in two large cracks about 1′ 10″. To the right, the lintel was fractured and broken off to the depth of 4¼″, as far as the end and top, *i. e.* 1′ 3″. The inner lintel was slightly disturbed in its bed, and the end behind the point struck, started in. The disturbance

TABLE No. 15—*Continued.*

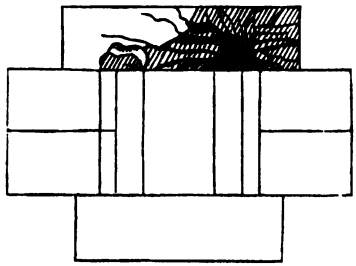
Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 26 and 27, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
								was barely perceptible; the iron was not moved; neither of the sill stones were at all disturbed. Slight cracks on the inner face extended to the top of the wall. The embrasure as serviceable as ever, and its general strength not at all impaired. Fig. U. 
204	8	10¼	Ball	68	¼	200	Centre of No. 7	Passed through without touching the embrasure.
205	8	10¼	Ball	68	¼	200	Do.	The ball struck the offset of the right shutter, the shutter being open, 4½″ below the top, lapping on the offset very nearly the entire breadth of the latter, say 3″; passed through this offset, and through three thicknesses of ½″ iron of the shutter between the offset and the hinge. The upper gudgeon of the shutter was broken off where it entered the socket, and the shutter entirely disabled. The ball was deflected from its direction, as it approached the throat plate, indenting the latter 1¼″ on the outer face, and ½″ in the inner face of throat plate. A small piece of the outer plate about 2″ square was broken off. The ball broke in many pieces, and was deflected through the screen to the left, carrying away a portion of the boarding, about 6′ by 4′. The cast-iron backing of the throat plate was broken through directly behind the ball, and a small wedge-shaped mass 8″ high, 4″ broad, and 1¾″ thick, was scaled off. The upper stone of the

TABLE No. 15—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 26 and 27, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
								inner cheek was broken through vertically at 15″ from the inner edge of the embrasure. This fracture probably passed through the inner dowel of the cheek stones. Near the cast iron, there was another crack across the lower corner of the upper cheek stones, which possibly passed through the outer dowel of the inner cheek. A wedge-shaped mass of stone 7″ broad by high, and 2″ deep at the thickest part, was scaled off the upper cheek stone near the iron. The inner portion of the broken cheek stone was pushed to the rear from 1″ to 2″, and the joint between it and the lintel considerably opened. Cracks in the inner face were considerably enlarged, and extended vertically to the top, and horizontally to the end of the wall from the lintel. The joint between the lintel and the other inner cheek was also disturbed. The lintel appears to have revolved about the inner vertical edge of the opposite cheek. The upper bed of the lintel was also disturbed 2′ to the right of the embrasure on the inside. The lower stone of the inner cheek on the side struck, was also slightly disturbed in all its joints, but not to move it from its position. The sills were not disturbed. Embrasure still serviceable by removing the broken shutter.
206	8	10¼	Ball	68	¼	200	Centre of No. 7	The ball struck the edge of the left shutter, which was open, about half way between the top and bottom, overlapping it about ⅜ the thickness of the shutter, cut out a segment of the inner plate 5½″ high and 3″ wide, was then apparently deflected very slightly to the right, cut its way through the offset of the shutter, and the perpendicular portion inside buckling the latter up against the throat plate. The shutter was completely disabled, the upper socket being forced entirely from its position. The throat plate showed a very slight bend, and the top was thrust in 1½″ towards the axis of the

TABLE No. 15—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 26 and 27, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
								embrasure, but nothing more. The ball was broken, and the pieces deflected against the opposite cheek (breaking the upper stone and detaching numerous pieces and causing numerous cracks in it), thence through the embrasure to the right, carrying away a portion of the screen measuring about 6′ by 3′. Nearly all of the stone offset in the outer cheek behind the shutter was carried away, and a wedge-shaped mass 2′ 4″ high, 1′ 4″ broad, and 6″ in greatest depth, was broken off the outer sill at the throat, between the iron and the pintle hole. On the outer face of the wall no additional cracks were visible. On the inner cheek opposite the side struck, the junction of cast iron and cheek stones was slightly disturbed. The cast iron on that side was not injured. Embrasure still serviceable by removing the shutters.
								NOTE.—At this stage of the experiments the disabled shutters were removed.
207	8	10¼	Ball	68	¼	200	Left cheek, No. 7	The ball struck the left throat plate 11½″ below the roof, overlapping the inner edge of the plate somewhat more than half the diameter of the ball; cut a segment from the outer plate of the throat piece 9″ high by 5″ broad, and small pieces from the two adjacent plates. The ball penetrated and bent the plate 4½″ before

Fig. V.

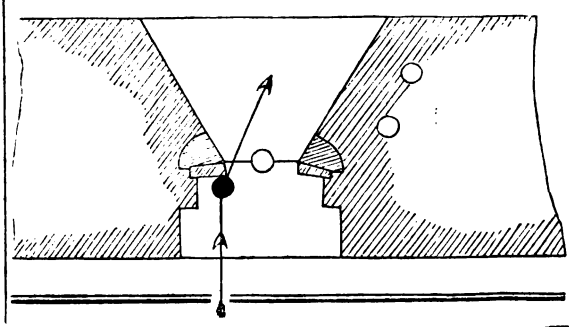


TABLE No. 15—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 26 and 27, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
								it glanced off. The plate was bent on the inside about 2½″, and thrust towards the axis of the embrasure ¾″ at the bottom, and ½″ at the top. Behind the wrought iron, a wedge-shaped mass of cast iron 2″ high by 10″ broad and 5½″ at its greatest depth, was broken off and thrown to the right and rear, in two pieces, one 10′ and the other 25′ distant. The fracture in the cast iron was continued into the cheek stones, breaking from them (about equally from each) a wedge-shaped mass, 2′ 6″ high, 9″ wide, and 2½″ average thickness. The top of the throat plate struck, was thrust in about ½″. Very little additional disturbance towards the rear at the bottom. Both the inner cheek stones on the side struck were disturbed in all their joints and thrust to the rear about ¼″ to ½″. No additional disturbance in the inner sill and lintel. The ball was probably not broken, and went to the right and rear. Embrasure still serviceable.
208	8	10¼	Ball	68	¼	200	Left cheek, No. 7	Ball passed through without touching.
209	8	10¼	Ball	68	¼	200	Do.	Ball struck the lintel about 1′ above the lower edge, and about 6″ to the right of the left outer edge of the embrasure. Ball broke and glanced downwards through the embrasure in many pieces, carrying away about ¾ of the outer lintel. The portion which remained was shattered into many pieces; its resisting powers entirely destroyed. No additional disturbance to the throat plate. The inner lintel was entirely carried away in two pieces, and two stones from the corner above it. The cheek stones remained as before. On the outer face of the wall, the cracks from the embrasure to the top of the wall were considerably enlarged. Embrasure still serviceable.
210	8	10¼	Ball	68	¼	200	Do.	Ball struck the left throat plate 5″ below the top, overlapping the right edge about ½ the diameter of the ball, cut out small segments from

TABLE No. 15—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 26 and 27, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
								the two outer ½″ plates, and was deflected to the right. All the eight plates were bent to the rear about 2″; some of them cracked. A piece of the inner one, about 1½″ wide, extending down 6″ from the top, was broken off. The top of the throat plate was set in towards the axis about ½″ more than it was before. No additional derangement in the sills or cheek stones. Embrasure still serviceable.
211	8	10¼	Ball	68	⅛	200	Left cheek, No. 7	Ball struck the left throat plate above the middle, passing to the rear between it and the masonry, and carrying the plate and the upper half of the cast-iron backing, about 20 yards to the right and rear. The inner opposite cheek was struck by some of the fragments, and the fractures enlarged. Another piece of the upper stone of the inner cheek was carried away, about 8″ wide, 1′ high, from 4 to 6″ thick. A piece of the stone above the outer lintel 17″ long and 1″ thick was also carried off. Embrasure still serviceable.
212	8	10¼	Ball	63	⅜	200	Do.	Ball struck the top of the right throat plate, knocked it and the cast-iron backing from its position, leaving them across the throat of the embrasure, and breaking off a wedge-shaped mass of stone 18″ long, 19″ high, and 4½″ in average thickness from the lower stone of the inner cheek. The ball glanced to the inner opposite cheek, starting the inner half of the upper cheek stone about 4″ to the rear, and cracking the other portion in all directions. The inner portion of the upper sill stones behind the side struck, was knocked off, the fracture passing through the inner dowel hole. Embrasure scarcely serviceable without some repairs. The stonework above the roof of the embrasure would require propping up by some timber to prevent the blast of the piece from bringing it down. The principal cracks in the cheek stones were through the dowel holes. This shot was broken.

TABLE No. 16.

FIRING AGAINST 2D TARGET WITH SOLID SHOT OF 128 POUNDS WEIGHT.

Gun 10 inch Columbiad, length 10′ 6″, weight 15,400 lbs.
Platform level with bottom of target.
Axis of gun 4 feet above platform.

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 28, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
213	10	18	Ball	128	1/8	114	Granite masonry between No. 7 and end of sill stone course	Ball struck at the point aimed at. Penetration 7¾″; was itself broken up, shattering the wall badly in all directions, and opening the vertical joints in many places, as much as 4″ to 6″. The ball struck a horizontal joint; shattered the upper and lower stones into a great many pieces. In rear of the point struck, two stretchers from 2′ to 3′ long were knocked out of the inner facing. All of the joints in the wall were disturbed by previous shots. The result was not, therefore, a fair test of the resisting powers of a 5 feet granite wall.
214	10	18	Ball	128	1/8	114	Granite between 7 & 8 on a line with the sole of the embrasure	A good line shot, but struck 1′ above the point aimed at; was broken as before. Penetration 10″. Shattered the two adjacent stones above and below, in all directions, and opened all the vertical joints to the top of the wall, in some places as much as 1″ to 2″. The stretchers in both courses between the stone struck, and the cheek stones of No. 7 were thrust out 2″ or 3″ *towards the battery*, revolving around the vertical edge farthest from the point struck. The horizontal courses below the stones struck, suffered very little disturbance. The ball struck 2′ 9″ from the brickwork. There was a general separation of the stone and brickwork to the top of the wall, but not extending below the course struck. On the inner face of the wall, there was little additional disturbance. Opposite the point struck, the stones did not appear to have been started in. One stone, about 2′ from the top of the wall, was started in about 1″.

TABLE No. 16—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object.	REMARKS—July 28, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
215	10	18	Ball	128	$\frac{1}{8}$	114	Charleston brick between 7 & 8 on a line with the sole	Ball struck the point aimed at. Penetration 3 feet 5½ inches. Exterior radius of crater 3 feet 3 inches. The ball unbroken remained in the bottom of the crater. To the right of the point struck, the openings caused by shot No. 214 were enlarged, and several additional cracks were made, extending obliquely to the top of the wall. On the inner face, the cracks did not appear to extend to the foundation of the wall. The inner stone facing, to the extent of 5′ high and 4′ broad, was knocked out, and nothing but broken fragments of concrete from the heart of the wall, covered the ball. Upon removing these by hand, the ball was discovered. A very little more powder would probably have sent it entirely through. The inner facing of the wall was rubble masonry, of small dimensions.
216	10	18	Ball	128	$\frac{1}{8}$	114	Northern brickwork	Ball struck about 1′ above the ground. Penetration 3′ 11″. Exterior radius of crater 2′ 3″. The wall was cracked to the top, but not badly, there being only one crack of that extent. The small cracks radiating from the crater were not generally more than 10″ or 1′ in length. About 5′ above the ball, there was a horizontal crack extending entirely across the brickwork between embrasures Nos. 8 and 9. This was caused in part by previous shots. The general effect of the ball in this brickwork was far less extensive than in the granite. On the inner face of the wall, cracks were made extending from top to bottom, though not large. Nearly all the horizontal joints were slightly disturbed. One stone, about 18 to 20″ square, directly behind the ball, was started to the rear about 9″, and the one above it from 3″ to 4″. The ball was not broken.
217	10	18	Ball	128	$\frac{1}{8}$	114	Charleston brick to left of No. 8	Ball struck about 3½′ to the left of No. 8, on a line with the sole. The ball passed unbroken through the wall, and about 20′ to the rear. Maximum

TABLE No. 16—*Continued.*

Order of firing.	Calibre.	Charge of powder.	Projectile.	Weight of projectile.	Elevation.	Distance.	Object	REMARKS—July 28, 1855.
No.	inch.	lbs.	kind	lbs.	degrees	yds.	at	
								radius of crater on the exterior face 2′ 10″. No extensive cracks in addition to those existing before on the interior of the wall; all the rubble (inner) facing, extending from Embrasure No. 8, nearly half way to No. 9, was carried away. In the part remaining, no additional cracks of great extent were caused.
								NOTE.—In the Charleston, as in the northern bricks, although the local effects are considerably greater than in the granite, the general effects are less extensive. There were fewer vertical cracks to the top of the wall.

SECTION VI.

Remarks as to Condition, Comparative Strength, &c., of the Two Targets.

Want of cohesion between materials in 1st target led to greater care in building 2d.

86. In noting the effects of firing upon the masonry of the first target, it was plain there was not so great a degree of cohesion between the mortar and other materials as had been expected from the pains taken in the construction. Whatever may have been the cause, this was made very evident by certain results in the course of the firing; and it induced more than common care, as to materials and workmanship, in the construction of the second target.

Solidity of 1st target,

87. As to comparative strength and solidity, therefore, the 1st target may, probably, be regarded as in no degree superior to walls of the same materials and age, in fortifications generally.

and of 2d.

88. While the second target, constructed with strict conformity to the instructions before quoted, was probably somewhat better than such walls.

89. Both were, however, much inferior in hardness and cohesive strength to what they would have become, even in some ten or fifteen years. And it is worthy of consideration that the brick, and the concrete portions, were much worse off in this particular than the part formed of granite blocks, since the importance of time, as an element of strength in constructions of this nature, is the greater as mortar enters in the greater proportion—that is to say, is of much more importance in brick masonry, or in concrete, than in stone masonry, or at any rate in coursed stone masonry; in the latter, its importance being inversely as the magnitude of the individual stones, that go to make up the wall. Cohesive strength and hardness of both targets.

90. The shutters of Embrasure No. 7 (2d target), though pretty well hung, were not perfectly centered; and the friction was therefore too great for them to close entirely by spontaneous movement, on the discharge of the gun—although one leaf closed, and remained shut, in one instance. The same leaf was about half closed by each of the other discharges; while the opposite leaf, more imperfectly centered, was found each time moved out only one or two inches from the cheek of the embrasure. When the gun was depressed about 4°, and trained at the same time about 30° away from the directrix, some injury was done to the shutter-catch on that side, owing to weakness in its confining bands. Action of shutters.

91. On the whole, there is no reason to doubt that shutters like these in the second target, heavy as they are, may be caused to close, of themselves, at each discharge. They must, however, be truly centered, and have strong, and freely moving hinge-pivots and latch. A stiff spring, acting on the back of each shutter, would, at any rate, insure the closing. Shutters may be made to close of themselves.

Mortar damp in breaches.

92. The mortar in the interior of the masonry and concrete of both targets, as exposed in the breaches, was, although to a certain degree solid and hard, decidedly damp, not to say wet—as was plainly shown by the darker color of the inner portions, and as was evident to the touch.

Both targets quite new.

93. Both targets were quite new—the time intervening from the completion of the first to its destruction, being about fifteen months; and with the second, about thirteen months.

Facts reported by Lt. Gillmore.

94. A close examination of the different kinds of masonry in the second target, after the firings had ceased, elicited the following facts, as reported by Lieut. Gillmore.

1st fact: relative adhesion of *concrete* to brick and stonework.

1*st*. The adhesion of the concrete to the brickwork was greater than to the stonework. The difference appeared to be considerable, and any material deviation from this result could always be traced to imperfect manipulation. Some of the irregular fragments of the wall broken off by the heavy shots, and containing from one to two cubic feet, were composed of brickwork on one side and concrete on the other, connected by a vertical plane surface joint, and after falling to the ground from a height of 8 or 10 feet remained unbroken. Of the two kinds of brickwork, the adhesion to the concrete proved to be largely in favor of the northern brick.

2d fact: adhesion of concrete masses to fragments of bricks, and stones, to gravel, and to each other.

95. 2*d*. In the body of the concrete, the adhesion of the mortar to the brick fragments was somewhat greater than to the stone fragments. The adhesion to the gravel which was rather smooth, and to the rounded stones placed in the different layers, was rather slight. It was found that, with every precaution, the junction between the masses of concrete made on different days, was always considerably less firm than between the consecutive layers made on the

same day; and the fractures from firing generally took place along these principal planes of division, first. Where the concrete formed a portion of the face of the wall, the termination of each day's work could generally be readily traced with the eye.

96. 3*d*. The fine concrete of Embrasure No. 9 was somewhat stronger than that adjacent to it on the face of the wall, though not to the extent which the double quantity of cement, which it contained, might lead us to expect. 3d fact: fine concrete of embrasure No. 9.

4*th*. The adhesion of the mortar to the brickwork appeared somewhat greater than to the stonework. It was difficult, however, to institute a comparison between these two kinds of masonry from the greater ease with which the brickwork could be examined. 4th fact: relative adhesion of mortar to brick and stonework.

5*th*. The adhesion to the mortar was greater in the northern brick than in the southern. In the former, indeed, this quality was quite remarkable, overcoming in many cases the strength and tenacity of the brick itself, when it was attempted to separate a joint with a chisel or hammer. In such cases generally the surface of separation after following obliquely for some distance the mortar of the joint, would branch off into the brick, giving in the two materials a continuous conchoidal fracture. In both kinds of brickwork the mortar appeared to be harder and stronger in proportion to its proximity to the face of the wall, indicating clearly that a longer time, and a more complete evaporation of the moisture, in the wall, was necessary for the mortar to attain its maximum strength and hardness. The same may be said of the concrete. 5th fact: relative adhesion of mortar to northern and southern bricks.

97. 6*th*. The adhesion of mortar to brick in the horizontal joints was thought to be somewhat greater than in the vertical ones; though to a very small extent. In laying up the brickwork every precaution was taken, and as this final examination showed with 6th fact: relative adhesion of mortar to bricks in horizontal and vertical joints.

complete success, to secure the most perfect contact, and the maximum density in the vertical joints, by using plenty of mortar, and forcing each brick well up towards those adjacent to it.

7th fact: relative adhesion, in horizontal joints, of bricks above or below the mortar.

98. *7th.* In the horizontal joints, no difference could be detected in the adhesion of the mortar to the bricks below, as compared with those above.

8th fact: advantage of soaking bricks.

8th. It did not appear that soaking the bricks in cream of cement gave better results than soaking in pure water. When the latter method is employed, the process loses much of its virtue, unless the bricks are laid as soon as they cease to drip, and before the film of water has left the surface; with a stiff mortar it was found that much better contact could be secured when the brick was quite wet at the moment of laying.

Thoroughly soaking the bricks will not suffice, unless they are laid with the free water upon the surface; if such be not the case, the mortar should be quite thin to insure a perfect contact; but by making it thin, its ultimate density is impaired.

9th fact: no advantage in soaking solid parts of concrete in cream of cement.

99. *9th.* It did not appear that the concrete was improved by soaking the solid parts in cream of cement instead of water.

CHAPTER II.

EFFECTS OF THE FIRINGS UPON THE DIFFERENT MATERIALS USED IN BUILDING THE SEVERAL EMBRASURES OF THE TWO TARGETS.

SECTION I.

Effects of firing from 42 *pdr. and* 8″ *Columbiad, with iron canister shot of* 1½ *lbs.;* 6.88 *oz.;* 5.10 *oz.; and* 3.33 *oz.—distance* 200 *yards.*

Upon granite.

100. *Upon granite.*—Generally no effect: when striking near edges or solid angles, producing cracks, knocking off pieces of stone, and driving several small fragments through the embrasure (105 and 107, Table No. 9), (16, Table No. 3). A piece broken off 8″ by 1½″ by several inches in depth (134 to 142, Table No. 10). Another 15″ by 4″ by 4″ (161, Table No. 12).

Upon brick-work.

101. *Upon brickwork.*—Holes were made in the brick facing, varying in depth and diameter with the size of the shot, the penetration being a little greater in the southern than in the northern bricks. Pieces were broken from edges (8 and 14, Table No. 2; 15, 20, and 22, Table No. 3). A piece 5″ by 4″ by 3″ broken out of arch. (117, Table No. 9.)

Upon cement-concrete.

102. *Upon cement concrete.*—Holes made in the face of the concrete—diameter 6″ to 10″, depth 2″ to 4″ (8, 10, 12, Table No. 2), (15, 16, 17, 18, 19, Table No. 3), (115 and 119, Table No. 9), (123 and 142,

Table No. 10). When a shot struck upon, or near, a solid angle, an irregular mass was knocked off from 6″ to 16″ in length, by 2″ to 8″ in breadth and thickness (9 and 20, Table No. 2), (120, 122, Table No. 9).

Upon asphaltic concrete.

103. *Upon asphaltic concrete.*—Holes made in the face 5″ to 7″ diameter by about 2″ depth (16, 18, 22, Table No. 3). One mass knocked off a solid angle, 7″ high by 4″ broad; another, 17″ high by 5½″ broad (17 and 20, Table No. 3). A shot struck 4″ from edge of asphalte, producing cracks 7″ to 8″ long, extending to edge (19, Table No. 3).

Upon lead concrete.

104. *Upon lead concrete.*—Holes equal, about, in width and depth to the diameter of ball—no cracks and no fragments of any size thrown off (17, 18, 21, 22, Table No. 3).

SECTION II.

Effect of firing from a 42 *pdr. and* 8 *inch Columbiad, with grape shot of* 4.20 *lbs. each—distance* 200 *yards.*

Upon granite.

105. *Upon granite.*—Generally no effect. One shot cracked off the corner of a granite block 8″ or 10″ (34, Table No. 4).

Upon brick masonry.

106. *Upon brick masonry.*—Craters were produced in the face about 8″ in diameter and 4″ to 5″ deep (23, 24, Table No. 4). At junction of brick and cement concrete the hole was 15″ in diameter by 3″ deep (28, Table No. 4). Shots struck near solid angles with various effects, generally, a few pieces of bricks were broken off (24, 34, Table No. 4), (179, Table No. 13). In one case (23, Table No. 4) the effect at the end of the target was considerably greater.

107. *Upon cement concrete.*—The holes in the face varied in diameter from 12″ to 15″, and in depth from 3″ to 4″ (25, 27, 37, Table No. 4). There were various effects according to circumstances (28, 31, 35, 37, Table No. 4). Upon cement-concrete.

108. *Asphaltic concrete*—was not struck. Asphaltic concrete.

109. *Upon lead concrete.*—An impression was made equal in depth to ⅛ the diameter of the ball, and of a diameter equal to that of the ball, which was not broken; no fragments beyond mere spiculæ thrown off, and no cracks. Upon lead concrete.

SECTION III.

Firing from a 42 pdr. and 8 inch Columbiad, with musket balls as canister shot—distance 200 yards.

110. Produced no effect upon any of the materials —the leaden musket balls being flattened upon all. No effect. Lead balls flattened.

SECTION IV.

Firing with 42 pdr., spherical case shot filled with musket balls—distance 200 yards.

111. *Upon granite.*—When granite was struck before the bursting of the shell, the effect was considerable—pieces being broken off—cracks produced—joints opened, and motion caused in joints (39, 42, 43, Table No. 5). Upon granite.

112. *Brick masonry*—was not struck. Brick masonry.

113. *Upon cement concrete.*—When a solid angle was struck, the effect was considerable—pieces, some- Upon cement-concrete.

times of large size, being knocked off (40, 41, 47, Table No. 5).

Upon asphaltic concrete.

114. *Upon asphaltic concrete.*—A shell striking perpendicularly on the face, produced a crater 2 feet in diameter and 7 inches deep. The bursting caused no further injury. The embrasure was still serviceable (48, Table No. 5).

Lead concrete.

115. *The lead concrete*—was not struck.

SECTION V.

Firing from a 42 pdr. with loaded shells—distance 200 yards.

Upon granite.

116. *Upon granite.*—The granite blocks near the right top course being struck, were considerably displaced (86, Table No. 7).

Upon brick masonry.

117. *Upon brick masonry.*—A crater was formed 2′ in diameter and 1′ deep; shell broken by the concussion (87 and 88, Table No. 7).

Upon lead concrete.

118. *Upon lead concrete.*—A crater was produced 1′ 4″ wide and 8½″ deep. The shell exploded in the crater—no cracks, and none but minute fragments sent off from the lead (88, Table No. 7).

Rubble masonry, cement-concrete, and asphaltic concrete.

119. *The rubble masonry, cement concrete,* and *asphaltic concrete*—were not struck.

SECTION VI.

Firing from a 24 pdr. with solid shot—distance 95 yards.

120. *Upon cement concrete.*—Ball, striking not far from left end and top of target, penetrated 1′ 10″—crater about 3′ 6″ in diameter, extending to top—cracked the wall through, and out to the end—ball did not break (182, Table No. 14). Upon cement-concrete.

121. Another, struck a little lower, entered 1′ 3½″, diameter of crater 2′ 6″—made a crack out to the end (about 5 feet), (183, Table No. 14). Another shot.

122. Another, penetrated (about 10″) to the outer sill stone, which is cracked slightly, as well as the inner one, without displacing either—cracking and disturbing a little, the brickwork and iron work of the throat of the embrasure (No. 9), see (184, Table No. 14). Another.

123. Another ball struck below Embrasure No. 9, at the junction of the cement concrete and brick-work, passed through a thickness of 2 feet into and through the tongue hole, which was 7 inches high: did not touch its top, bottom, or sides, carried away a mass of concrete in front of the sill, which it cracked but did not disarrange (see 185, Table No. 14). Another.

124. Other shots from the 24 pounder aimed chiefly at the iron work of the embrasure, broke away more or less of the contiguous concrete and brickwork. Effects upon the iron work to be stated further on. Other shots.

SECTION VII.

Firing from a 42 pdr. with solid shot—distance 200 yards.

Upon granite.

125. *Upon granite.*—The craters formed in this material by shots striking perpendicularly, were of irregular form—from 1½ to 3 feet in diameter, and in depth about 4 inches. When the balls struck near edges, fragments, sometimes large, were broken off; and in some cases fragments of the stone and of the shot, passed through the embrasure, tearing away large portions of the screen behind. Moreover, cracks were thrown off to a considerable distance from the point struck, often entirely through the largest stones. Joints were opened for some distance. The balls were generally broken (see 57, 58, 59, 60, 61, 77, 78, 79, 80, 83, 84, Table No. 7).

Upon rubble-work.

126. *Upon rubble-work.*—The interior rubble facing of the target, which was of rather small stones, and not well tied to the wall by headers, was started inwards in one or two cases; and was frequently cracked and jarred.

Upon brick-work.

127. *Upon brickwork.*—When the ball struck the wall perpendicularly, the craters formed were in diameter about 2′ 6″ and in depth from 1′ 6″ to 2′. Where the rear lining of the target was of brickwork, the portion behind the crater was considerably cracked and jarred. The greatest effect was produced by shot No. 65, Table No. 7, which see. The balls generally did not break (49, 59, 60, 64, 65, 66, 68, 69, 70, 72, 76, Table No. 7).

128. *Upon cement concrete.*—The effect was great, particularly when the balls struck near a solid angle; considerable masses were then broken off; cracks were generally produced, with a shattering of the material. Balls sometimes broken and sometimes not. (61, 62, 63, 64, 76, 81, 82, Table No. 7.) Upon cement-concrete.

129. *Upon asphaltic concrete.*—Effects very decided. The concrete was either removed entirely when struck, or very much cracked and shattered. (66, 72, 73, 83, Table No. 7.) Upon asphaltic concrete.

130. *Upon lead concrete.*—The effect was very favorable to this material; the penetration was 12 inches, and the diameter of the crater from 14″ to 15″, of very regular form—no fragments of any size—no cracks. The balls were broken and stopped. (49, 67, 70, Table No. 7.) Upon lead concrete.

SECTION VIII.

Firing from 8-*inch Columbiad, with solid ball of* 68 *lbs. Distance* 200 *yards.*

131. *Upon granite.*—When the stone was struck directly, as in 203, 209, Table No. 15, the effect was great, fragments of stone being broken off, sometimes large, and carried through the embrasure with much force—extensive cracks being produced, and joints opened, and disturbed in the vicinity of the point struck, both on the inside and outside of the wall. When the irons were struck, the granite in contact with them was broken, cracked, and shattered—joints being opened or jarred in some instances for a considerable distance from the point struck. (196, 199, 203, 205, 206, 209, 211, 212, Table No. 15.) The Upon granite.

balls were generally broken, and passed through the embrasure in fragments, tearing away, with pieces of stone, large spaces from the screen.

Upon brickwork.

132. *Upon brickwork.*—A considerable crater was produced by striking this material. Generally the effect seemed confined to the immediate vicinity of the point struck; although in some cases there were pieces of the brick wall broken off, and cracks produced on the inside as well as on the outside of the wall. (195, 196, 197, 199, Table No. 15.)

Upon cement concrete.

133. *Upon cement concrete.*—The penetration seemed to be about two feet (193, Table No. 15). Cracks were formed, extending for several feet in different directions. The material was much shattered at, and near, the point struck. When striking cement concrete alone, the balls were not broken generally.

Upon rubble masonry.

134. *Upon rubble masonry.*—This was not struck in this firing, but the effect of the ball was, in many cases, transmitted through the wall, and where the inner face was of rubble, caused cracks therein, and occasionally threw off small portions that were not well tied in.

Asphaltic concrete.

135. *The asphaltic concrete* was not struck in this firing.

SECTION IX.

Firing from 10-*inch Columbiad, with solid balls of* 128 *lbs. Distance* 114 *yards.*

Upon granite.

140. *Upon granite.*—The penetration in granite was from 7¾ to 10 inches—the effect was to shatter, crush, and crack in all directions, the stones at and

near the point hit. Joints between the granite blocks were opened, sometimes as much as four inches. In the firing (214, Table No. 16) two of the blocks near the point of impact were, by reaction, brought out 2″ or 3″ in a direction opposite to the shot's motion—that is to say, towards the gun. The effect upon the surrounding bond was much less—indeed, it was quite slight in directions where there was firm support, that is, towards the foundation, and towards the left—than upwards and towards the near right end of the target. Some rubble-stones in rear of the points struck were knocked out of the rear facing. (213, 214, Table No. 16.)

Rubble.

141. *The rubble* was not hit by these balls; but when it formed the inner facing of the target, behind the point of impact, it was started from its bed, and sometimes stones were thrown entirely out. (214, 215, 216, 217, Table No. 16.)

Upon brick-work.

142. *Upon brickwork.*—Although the local effects in this material appeared to be considerably greater than in granite, the general effect was less widespread; but this may have partly, at least, been due to its being supported on both sides, while the granite was sustained on one side only, by much masonry. There was no apparent difference as to resistance, between the northern and southern bricks. In one case (217, Table No. 16), the ball passed entirely through the wall. But it is essential to bear in mind, as to all these effects, that the target was then very much shattered by previous firing. Of course the resistance to many of these heavy balls was considerably less than it would otherwise have been. (214, 215, 216, 217, Table No. 16.)

Cement concrete.

143. *The cement concrete* was not struck by any of these 10-inch balls.

CHAPTER III.

EFFECTS OF FIRINGS UPON THE IRON SHUTTERS, THE IRON FACINGS, AND THE IRON THROAT PIECES OF THE EMBRASURES.

SECTION I.

Effects upon the shutters of ½″ boiler iron, produced by musket balls, canister shot, and grape shot, fired from large guns within short distances.

Of musket balls.

144. *Musket balls* produced no effect.

Of canister shot, weighing each 5.10 ozs.

145. *Canister shot*, weighing 5.10 ounces, made a rather slight indentation. In one case the plate of iron was cracked open. In another, a piece one-half the size of the ball was cut out of the edge; and in another, the hinges were broken or strained. (15, 20, 21, 22, Table No. 3.)

Canister shot of 1½ lbs. weight.

146. *Canister shot*, weighing 1½ lb. each, produced in these shutters depressions from ½″ to ¾″ deep—one shot caused a crack. (14, Table No. 2.)

Grape shot of 4.20 lbs. weight.

147. *Grape shot*, of 4.20 lbs. each (diameter 3″.17) passed through, or entirely carried away, these ½ inch shutters. (25, 28, Table No. 4.)

Spherical case shot.

148. *A spherical case shot* struck one of these ½″ shutters, and cut out a segment 9″ high, and 2½″ broad; but the shutters were notwithstanding left on their hinges. (47, Table No. 5.)

SECTION II.

Effects of firing upon the shutters 1½ inch thick, composed of three plates of ½ inch boiler iron, well riveted together.

149. *Canister shot, weighing* 3.33 *ounces*, made only a slight indentation on these shutters, one shot striking the latch, disabling it temporarily. (158, 160, 161, 162, 163, 176, 177, Table No. 12.) Canister shot of 3.33 ozs. weight.

150. *Canister shot, weighing* 1½ *lb.*, produced indentations ¼″ to ½″ deep, and 1¾″ in diameter. One shot broke off horizontal portion of the latch. (105, 106, 114, Table No. 9.) Canister shot of 1½ lb. weight.

151. *Grape shot weighing* 4.2 *lbs.*—Made an indentation 4″ diameter and ⅛″ deep; the shutter was slightly bent; the shot was broken and stopped. (180, Table No. 13.) Grape shot of 4.2 lbs. weight.

152. *Solid shot of* 68 *lbs.*—The shutters being open were struck, in one case upon the offset, in the other upon the edge. In both, the shutters were much injured and disabled. (205, 206, Table No. 15.) Solid shot of 68 lbs. weight.

SECTION III.

Effects produced upon the boiler iron facings (½″ thick) of the offsets of the embrasures, by musket balls and canister shot.

153. Musket balls and canister shot, varying in weight from 3.33 oz. to 1½ lb., produced no injurious effect—that is to say, when the offsets of the embra- Musket balls and canister shot, varying in weight from 3 33 ozs. to 1½ lb.

sures were thus covered, no fragments were broken from them and carried through the embrasures, as was the case from unprotected facings of stone, bricks, or cement, or asphalt concrete. The indentations in these iron plate coverings of half an inch in thickness, made by the 1½ lb. canister balls, were from ¼″ to ¾″ deep and 1½″ in diameter. (115, 119, Table No. 9; 123, Table No. 10; and from 158 to 177, No. 12, inclusive.)

Grape shot did not strike.

154. In no instance were these half-inch coverings struck by grape shot.

SECTION IV.

Effects produced upon the 2-inch offset plates of wrought iron inserted in the outer cheeks of Embrasures Nos. 4 and 5.

Effect of 42 pdr. balls.

155. A 42 pdr. ball struck one of these 2-inch plates, broke a piece out of it, and jarred the whole of that cheek; it was itself broken thereon. Another struck the left throat plate, also two inches thick, cutting out a piece about ⅓ the area of the ball, which passed on; it, besides, bent the plate a little, and jarred it in its position. Another struck on outer offset plate, broke a piece out of its middle, passed on, and was stopped by, and broken on, the second plate, which was uninjured. (49, 50, 64, Table No. 7.)

SECTION V.

Effects of firing upon the wrought-iron throat pieces.

Musket balls, canister shot, and grape shot of 4.2 lbs. weight, stopped.

156. The throat pieces of Embrasures Nos. 3, 4, 7, 8, and 9, stopped musket balls, canister shot of all sizes, and also grape shot of the weight of 4.2 lbs., no effects being produced upon them, except unimport-

ant indentations. (18, 20, 22, Table No. 3; 30, Table No. 4; 51 to 56 inclusive, Table No. 6); and (107, 113, 116, 122, Table No. 9, to 138, Table No. 10; 143 to 157, Table No. 11; 158 and 161, Table No. 12.)

157. A 42 pounder spherical case shot, weighing 39 lbs., struck shutter of No. 3, near its junction with gorge plate, indented the plate to the depth of about 2½ inches, and caused a considerable bending of the whole plate. (47, Table No. 5.) A 42 pdr. spherical case shot.

158. A solid shot from a 24 pdr., distant 95 yards, was well resisted and entirely stopped, by the throat plates of No. 9. But after several shots had struck the same plates, the injury was considerable—the final result being the entire removal of the plates. (189, 190, 191, and 192, Table No. 14.) A 24 pdr. solid shot, at distance of 95 yards.

159. Some 42 pdr. solid shots striking gorge plates of No. 3 and 4, bent them, and finally tore them from their fastenings. (63, 66, and 74, Table No. 7.) 42 pdr. solid shots.

160. The throat plates of No. 8, on being struck two or three times by 68 lb. solid shot, were carried away, the cast-iron backing being cracked and having pieces broken off. 68 lb. solid shot.

161. A 68 lb. ball striking the right shutter and throat plate of No. 7, was broken into many pieces, impressing the throat plate to the depth of 1¼ inch, but not displacing it—destroying the upper part of the shutter. (205, No. 15.) Another 68 lb. ball.

162. Another 68 lb. ball striking the left shutter of No. 7, destroyed it, was itself broken, and deflected in fragments by the resistance of the throat plate, which was but little disturbed. (206, No. 15.) Another 68 lb. ball.

163. Another ball of the same calibre struck the same throat plate, and was deflected from it. (207, No. 15.) Another.

Another. 164. Another 68 lb. ball was received by the same throat plate. (210, Table No. 15.)

Another. 165. Still another, which carried it away. (211, Table No. 15.)

Another. 166. Another struck, with about half its diameter, the left throat plate of No. 8, near the top, cut out a portion, broke off some fragments from the thin plates of which it was composed, was deflected—did not materially disturb the position, or change the form of the throat plate. (196, Table No. 15.)

Another. 167. A 68 lb. ball was broken on the left inner edge of the left throat plate of No. 8, doing little injury to the plate, but forcing it into an inclined position in the throat of the embrasure—this movement of the throat plate in its own plane was partly owing to the damaged state of the embrasure. (197, Table No. 15.)

Another. 168. The next shot hit, and carried entirely away, this throat plate. (198, Table No. 15.)

Another. 169. Another of these balls penetrated between the right throat plate of No. 8 and the brickwork, carrying the throat plate through the embrasure. (199, Table No. 15.)

CHAPTER IV.

EXPERIMENTS UPON THE EFFECTS OF THE BLAST OF GUNS.

SECTION I.

Table No. 17, *with preceding remarks.*

Attempts made to measure cone of blast of casemate gun.

170. THE course of the preceding experiments having shown, more and more clearly, the great advantage of a reduction in the size of the opening of the embrasure at the throat, as well as at the exterior face of the wall; some attempts were made to measure the cone of blast at the mouth of the casemate gun, as it was important to know how near the path of the ball the solid angles forming the throat might be brought, without danger of being deformed, or destroyed by the blast of the discharge—these solid angles being, even in the most oblique direction of the gun—namely, 30 degrees from the directrix—only 2½″ in advance of the plane of the muzzle.

Experiments made at West Point, August, 1855.

171. On some suggestions from the chief engineer, the following experiments were therefore made at West Point, in August, 1855, under the direction of Major J. G. Barnard, of the corps of engineers, then Superintendent of the Military Academy, who committed the execution to Major Fitz John Porter, of the artillery, and Lieut. Donelson, of the engineers.

TABLE No. 17.

EXPERIMENTS FOR FINDING THE CONE OF BLAST OF A CASEMATE GUN.

Gun 42 pdr., length 10′ 4″, weight 5,790 lbs.

Order of firing.	Calibre.	Charge.	Weight of ball.	REMARKS—August 14, 15, and 16, 1855.
No.	lbs.	lbs.	lbs.	
1	42	10	42	Two planks of 1¼″ thick and 13⅜″ wide, were set up in front of the gun, 6″ from its muzzle. A cut was made in each of them, so that when they were united, there was a rectangular hole for the ball to pass through. Figure 44, Plate IX., shows the distances of the prolongations of the sides of the bore from the edges of the rectangular hole. The gun was mounted at the dock, about 25 feet from the edge of the water. The planks were retained upright by being nailed to the pintle block. The planks were blown to pieces and thrown into the water. None of the pieces were found.
2	42	10	42	Two logs of wood, each hewed down on one side so as to be about 6½″ through, were set up in front of the gun, as were the planks in the last case. Figure 45 shows the position of the rectangular hole through the timber with relation to the muzzle and bore of the piece, as in the last case. The logs were blown into the water. A not found. B was found about 30 yards to the front and left of the gun. The blast appeared to have had no effect upon it, except to blow it away as aforesaid.
3	42	10	42	Two strips of pine plank, 4′ by 2″ by 1¼″, were nailed to pintle block, so as to be upright 6″ in front of muzzle of gun, their 2″ sides parallel to its axis. Figure 46 shows the relative position of the gun and strips. A was broken off 9″ below muzzle, B 12″. The pieces were not found. The part where A was broken was blackened as if by smoke.
4	42	10	42	Two hickory poles, each about 4′ long, and 2″ in diameter, were nailed to pintle block 6″ in front of muzzle of gun. Figure 47 shows their distances from the prolongation of the sides of the bore. The poles were blown away, and not found. The nails securing them were some drawn and some broken.
5	42	10	42	Two boards, each 1¼″ thick, were prepared as indicated in Figure 48. These were set upright, as indicated in horizontal and vertical projection, Figures 51 and 52. The 7″ edge rested on the pintle block. *a*, in Fig. 52, was a piece of board nailed to A and B at top; *b* was one nailed to their outer edges. A brace rested on the middle of *b*, its other end being supported by a picket driven into the ground. A and B were, in addition, secured to the pintle block by nails. *a* was thrown about 30 yards to the left and rear of the gun, *b* and the brace resting on it were not much displaced. The upper end of the brace was blackened as if by smoke. A and B were each thrown a few yards outward from the gun. Figs. 49 and 50, show the con-

TABLE No. 17.—*Continued.*

Order of firing.	Calibre.	Charge.	Weight of ball.	REMARKS—August 14, 15, and 16, 1855.
No.	lbs.	lbs.	lbs.	
				dition of A and B after the firing. The heavy dotted lines indicate where they were broken or split. The space which was blackened on A and B, immediately in front of the muzzle of the gun, was terminated by a curve, this not being distinctly traceable, nor perfectly regular, the blackened space not terminating abruptly on the board. No difference was observed in the curves on A and B. If we intersect the cone of blast by a plane *mn* (Fig. 51), at a distance of $5\frac{1}{3}''$ from the muzzle of the gun and normal to its axis, where this plane cuts the curves just described, will be points in the circular section of the plane and cone, and the radius of this section will be the hypothenuse of the right angled triangle, whose base is *or* and whose perpendicular is the observed ordinate of the curve. The distance *rs* corresponding to $op=5\frac{1}{3}''$ is $5\frac{1}{2}''$ (nearly); and by a measurement, as accurate as possible, of the ordinate *rt* of the blackened area (Fig. 49), corresponding to an abscissa $sr=5\frac{1}{3}''$, this ordinate is found $=10\frac{1}{2}''$. From the proportions of the figure, the distance *or* (Fig. 51) is $4.8''$ nearly. Hence the radius of this circular section will be $=\sqrt{(10.5'')^2+(4.8'')^2}=11.5''$ nearly. At the muzzle, the radius is of course that of the bore of the piece, viz., $3\frac{1}{3}''$. By the construction (Fig. 53), the angle *bdc* will represent the *flare* of the cone of blast; in this case about 55° 52′.
6	42	10	42	A frame consisting of 4 pieces of 5″ pine scantling was prepared, as indicated in Fig. 54. To the inner side of this and at a distance of 6″ in front of the muzzle, were nailed two hickory strips, each smoothed on two sides, and each $4\frac{1}{3}''$ by $2\frac{1}{4}''$ by $1\frac{1}{4}''$. Figure 54 indicates their distances from the prolongations of the sides of the bore. The frame was braced at *a*, *b*, *c*, and *d*, by $4\frac{1}{2}''$ scantling running to the front and resting against pickets. It was also secured to the pintle block by nails. After the firing, the top and sides of the frame, and the upper braces, were blackened as if by smoke. Strip A was thrown in the water 100 yards to the front, B was thrown 15′ to front. Fig. 55 shows the limit of the space on B which was blackened. The nails were, some drawn, and some broken. If we suppose the lines *a b*, and *c d*, Fig. 55, to be the intersections of the cone of blast with B, the radius, 6″ from the muzzle, would be, by a calculation similar to that made in the preceding case, 19″; and the angle of flare $bdc=68°\ 50'$.
7	42	10	42	Arrangements same as for the last, except A and B (Fig. 57) were 7″ and 8″ respectively from the muzzle, and B was $5\frac{1}{2}'$ long. The frame sprung a little to the rear. Frame, &c., blackened as in last case. A thrown in the water, to the front and right of the gun 20 yards. B thrown down by the muzzle and bent so as almost to be broken in two in the middle. The figure (58) shows the space on B that was blackened. The radius of cone, deduced on the same supposition as in the last case, will be nearly the same as before, 19″, giving about the same angle of flare. (See Fig. 59.)

TABLE No. 17—*Continued.*

Order of firing.	Calibre.	Charge.	Weight of ball.	REMARKS—August 14, 15, and 16, 1855.
No.	lbs.	lbs.	lbs.	
8	42	10	42	Arrangements same as for the last, except A and B (Fig. 60) were 9″ and 10″ respectively from the muzzle, and B was 4½′ long. A was thrown just in front of the frame, B was loosened but left standing. Figs. 61 and 62 show the spaces on A and B that were blackened. The radius of cone resulting from the dimensions 2′, Fig. 61, is 1′ 5½″. That resulting from the dimensions 2′ 4½″, Fig. 62, is 1′ 7⅜″. The corresponding angles of flare are 69° 26′ and 66° 51′. (Figs. 63 and 64.)
9	42	10	42	No strips nailed to the frame. The gun was elevated so that the prolongation of the top of the bore passed 12″ below the cap sill of the frame. The firing produced no effect.
10	42	10	42	Arrangements same as the last, except the prolongation of the top of the bore passed 11″ below the cap sill. The frame sprung back a little and was jarred very much. No other effect.
11	42	10	42	Arrangements same as the last, except the prolongation of the top of the bore passed 10″ below the cap sill. The frame sprung back, was jarred very much, was tilted up at *g*, Fig. 54, and was thrown clear of the brace at *b*. No other effect.

SECTION II.

Table No. 18, *with preceding remarks.*

Further experiments.

172. Some further experiments of the same nature were next tried by the same officers—receiving the

Blast of 24 pdr.

blast of a 24 pdr. gun on one of the wrought-iron throat plates, that had been used as a throat plate in an embrasure of the masonry targets just demolished.

Materials used in experiments.

173. In order to this, a chestnut log, having the dimensions given in Figs. 65 and 66 of Plate IX., was hollowed out to receive the two sets of iron plates—each set composed of eight half inch sheets—which were secured in their position by wedges. The log was then set upright in front of the gun, so that the edges of the plates should be at the distances

given in Figs. 65 and 66 from the muzzle and axis. The lower end of the log was buried a foot and a half in the parapet of the battery at the dock, and earth well rammed around it; and it was braced at top and near the ground.

These two plates, considerably distorted by previous firings, were the only ones not entirely ruined.

TABLE No. 18.

EFFECTS OF THE BLAST OF A 24 PDR. UPON WROUGHT-IRON THROAT PLATES.

Gun 24 pdr., length 10′ 4″, weight 5,790 lbs.

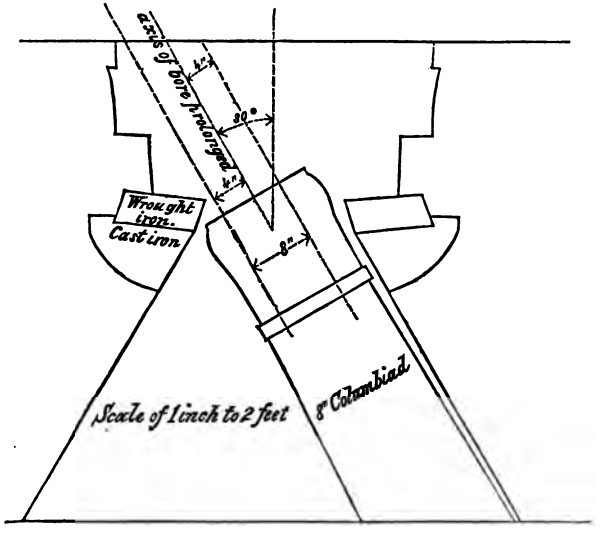
Order of firing.	Calibre.	Charge.	Weight of ball.	REMARKS.
No.	lbs.	lbs.	lbs.	
12	24	6	24	Tore off the bark on the outside of the log. Loosened a piece of wood which was between the two sets of plates. Separated the 1st outer sheet from the 2d sheet, $\frac{1}{8}$″ from the top, three-quarters of the way downwards. Also in the same way, the 5th from the 6th, one-sixteenth of an inch.
13	24	6	24	Split the log half through along the dotted line *z z*, Fig. 66; separated the 2d and 3d, and 7th and 8th, one-sixteenth of an inch from the top, half way down; separated the two sets of plates, so that there was a space between them of $1\frac{1}{4}$″ at top, 1″ in the middle, and $1\frac{1}{2}$ inch at the bottom. They were previously separated by a board about $\frac{1}{2}$ an inch thick.
14	24	6	24	Split the log almost entirely across, the split being $1\frac{1}{4}$″ wide in front. Separated a little more from each other, the sheets before opened. Separated the two sets of plates, so that the interval between them was $2\frac{1}{4}$″ at top, $1\frac{1}{4}$″ in the middle, and $1\frac{3}{4}$″ at the bottom.
15	24	6	24	Split off outer piece of the log entirely, but did not blow it away; displaced the braces *c* and *d*, Fig. 65. Separated outer sheet from the rest, and threw it 30 feet to the front in the water. Separated the 2d sheet from the 3d, so that the interval was one-fourth of an inch at top, and one-sixteenth at bottom. Separated the first four sheets of the second set, so that each two were $\frac{1}{8}$″ apart in the middle. Separated the two sets of plates so that they were $3\frac{1}{4}$″ apart at top, $2\frac{1}{4}$″ in the middle, and $2\frac{1}{2}$″ at the bottom. The head of the rivet at *a*, Fig. 65, and 2 inches of the outer end of the rivet at *b*, were broken off.

TABLE No. 18—*Continued.*

Order of firing.	Calibre.	Charge.	Weight of ball.	REMARKS.
No.	lbs.	lbs.	lbs.	

The Fig. AA shows the position of the muzzle of the 8-inch Columbiad, traversed 30° from the directrix with reference to the throat plates, as they were in the embrasure target.

Fig. AA.



CHAPTER V.

GENERAL REMARKS AND CONCLUSIONS.

SECTION I.

Conclusions as to effects of various missiles upon different materials of embrasures.

Conclusions, from preceding, as to respective resistances to heavy balls, of granite, &c., improper.

174. It would be improper to deduce strict conclusions from these firings, as to the respective resistances to heavy balls, afforded by granite, brickwork, and cement concrete, since a few months only had been allowed for the mortar, on which the strength of the last two depends, to harden. Walls of well jointed, large stones, would receive but little additional strength against a force of this nature, by the induration of its thin joints of mortar; while much of the strength of brickwork, and all the strength of cement concrete, would depend thereon. The short periods of 15 months, and 13 months, could not be expected to bring these materials into comparison with granite in this respect. As anticipated, therefore, their resistances were decidedly less; and of the two, for the same reason, if for no other, the cement concrete proved to be weaker than the brickwork.

Some peculiar comparative effects worth mentioning.

175. There were, however, some peculiar comparative effects worth mentioning. For instance the force of the heavy balls seems, in the softer materials, to be felt only at, or very near, the place of impact; and, so to speak, is absorbed there—the ball, unbroken, crushing its way further and further into the mass.

On the granite, however, these balls were themselves broken, with but slight actual penetration into the stone, throwing off cracks certainly, but with little local crushing—the remainder of the force being disposed of in jarring and vibrating the wall, to an extent that started from their beds quite distant stones.

Vibration of the wall.

176. From this vibration of the wall, so much more energetic in the granite portion of the targets than elsewhere, rubble-stones of the inside facing—not always directly behind the point struck—were thrown out by the first motion of the wall, as pushed over by the ball; and three or four stones were moved out of their beds, *towards the gun*, so as to project three or four inches from the plane of the wall, being left behind by this first motion, or projected forward by the returning motion of the wall—stones, moreover, that were well jointed, well bedded in mortar, and of the dimensions of about 3′ by 1′ 6″ by 1′ 6″—while there was also considerable disturbance of all the other stones quite out to the right (the nearest) end, and up to the top of the target. This motion of the granite stones was very slight downward, where the target was supported by the earth, on which it rocked; or to the left, where the stones were bonded into a considerable length of brickwork and concrete. The energy of these vibratory movements was very great, as the effects demonstrated; and though the space moved through was no doubt small, it might have been measured, had anything so marked been foreseen and provided for.

Marked effects.

Great energy of vibrating movement.

Space moved through small.

Small penetration into granite of heaviest balls.

177. The heaviest of the balls fired (weighing 128 lbs.) penetrated, as above stated, a little way only into the granite blocks; but even the smallest of the cannon balls, namely, 24 pdrs., caused, as well as the larger ones, at the first blow, cracks that extended in

The smallest balls making cracks.

several directions entirely through the stones hit. It was so with the larger blocks, as well as with the smaller ones—the succeeding balls finding these stones in a condition to be easily reduced to small fragments and dust. It may be expected, from effects of this nature observed, that under the impact of heavy balls, with high velocities, these cracks, though perhaps scarcely perceptible at first, will extend as far as the crystalline continuity is unbroken—that is to say, to a joint, or quite through the largest stones that happen to be hit; and hence there will not probably be the additional resistance afforded against such battering, by the use of very large stones, as their appearance would seem to promise; or as would justify much additional expense in providing inordinate sizes.

Probable extent of cracks in large crystalline stones.

178. There is no doubt, however, that concretionary stones, as "sand stones," would exhibit, under such trial, less brittleness than those of crystalline structure. Very large dimensions are more advantageous, in some other respects, perhaps, than in this.

"Concretionary stones" less brittle.

179. The balls, whether large or small, that struck the granite under an angle that deflected them, unless the angle was very acute, were broken into many pieces, all of which passed on. If not deflected, they were crushed up into a mass of slightly cohering fragments and fine particles. In several instances, grape, or canister shot, striking the oblique cheek of a granite embrasure, were broken into numerous fragments, all of which were deflected in, through the throat of the embrasure—several having force enough to pass through the boards of the screen—very many smaller pieces and spiculæ burying themselves more or less in the wood, with a force that would cause serious wounds in human flesh.

Balls, when deflected from granite, broke into many pieces.

If not deflected, were *crushed*.

Effects of brickwork and cement concrete on large balls and grape.

180. It was seldom or never that a large ball was broken, on striking either brickwork or cement concrete. In one instance, a grape shot, on hitting the oblique cheek of a brick embrasure, was broken into two pieces, that were reflected through the screen. In all others, when thus thrown off from bricks or cement concrete, they passed on through the throat, and through the screen—making only one hole each in the latter.

Brickwork and cement concrete as materials for flaring cheeks of embrasures.

181. The injury done to these oblique cheeks, by these smaller balls, was of no consequence, with either of the materials above mentioned. In reference to this particular point, therefore, namely, protection from small missiles—brickwork and cement concrete are better materials, very decidedly, for the faces of an embrasure of the established form, that is, with flaring exterior cheeks, than granite, or any other very hard substance.

Effects of grape and canister, striking near margins of openings.

182. From all the exterior embrasure-facings, except that made of lead concrete, when grape or canister shots struck near the margin of the opening, considerable, and sometimes numerous, fragments were torn from the facings, and thrown into the embrasure; and, when the cheeks were flaring, through the throat and against the screen. Though the granite was in this respect the best material of the three, effects of this kind were, nevertheless, quite serious from it also. In one instance, pieces were torn off by a grape shot from the lower edge of the lintel, for a length of two feet, and with a cross section of some six or eight square inches—the pieces being thrown through the throat. All the embrasures were considerably changed in their outline, by injuries thus inflicted; and there was no point more clearly established by the firings, than the necessity of protecting from small missiles, the external mar-

Necessity of protecting the masonry facings.

gins of all masonry embrasures, by plates of wrought iron or some other device. This will be necessary with any form of embrasure; but more especially, when the outer cheeks are so inclined as to reflect all fragments through the throat.

Plates of boiler iron protected offsets.

183. Plates of half inch boiler iron were found to protect perfectly the offsets in the cheeks of the brick-work, and cement concrete, embrasures; and may therefore be relied on to defend the external margins from these injuries.

Asphaltic concrete unexpectedly brittle.

184. The asphaltic concrete was brittle, under the action of even the smaller balls, to an unexpected degree; although the season of trial was summer. And in other respects, it did not compare with either of the other materials. It could hardly have been relied on to retain its form, had it been made softer, by a larger proportion of bitumen. It may, nevertheless, be useful in special applications about embrasures and loopholes.

Next to wrought iron, lead concrete the best material tried.

185. Next to wrought iron, lead concrete proved to be much the best of the materials under trial. The first use made of it, in constructions, so far as I know, was by Major R. Delafield, of the Corps of Engineers, U. S. Army, in forming the exterior cheeks of case-mate embrasures. Although less resisting, and more costly, than wrought iron, it is an admirable material for certain parts of embrasures; because, while it is very resisting, and will not crack, nor splinter, it can, with the utmost facility, be applied to the filling solidly, of irregular spaces, and to the reinforcing of weak places, not easily strengthened otherwise. Heavy balls, under high velocities, penetrate into it, a little more than their diameter, moulding for themselves a symmetrical bed, in which they are found crushed. They send no cracks through the mass;

By whom first used.

An admirable material for certain parts.

Effects of heavy balls.

they detach no fragments—none at least that are not very small, and harmless; they form a tulip-shaped crater, the outer edges rising above the general front surface, and curving gracefully away. The adjoining masonry is somewhat jarred, but in this respect the injury is as small as it can be in any combination.

Of grape and canister.

Grape shot (of the weight of 4½ lbs.) produce, on a small scale, effects just like those of cannon balls—so do canister shot. Neither grape nor canister shots were broken thereon. No balls, as it chanced, were deflected from it.

Important conclusions as to wrought iron. First; as to use of 8″ plates.

186. Some important conclusions may be drawn from the results with wrought iron.

First. It may be fairly assumed, that a plate, eight inches thick, of wrought iron of good quality, kept in place by a backing of three feet of strong masonry, will stop a solid ball from an 8-inch Columbiad fired with 10¼ lbs. of powder, from the distance of 200 yards. The plate of iron will be deeply indented at the point of impact, the ball carving for itself a smooth bed, of the shape and size nearly of one hemisphere, in which it will be found broken into many pieces easily separable; and it will, besides, be somewhat bent, generally. The masonry behind will be much jarred; and unless strongly bonded, be considerably displaced; moreover, unless the thickness of three feet is well tied into thicker masses immediately adjacent on the sides, and above, and below, the general damage will be severe.

Second conclusion: a single plate better than a *made-up* plate of same thickness.

Second. This plate will be much the stronger for being in a single mass, and not made up of several thinner plates. The continuity, effected by bolts and rivets, of the made-up plates, is broken even by weak assaults, so that afterward, the stronger, instead of a

joint opposition, finds only a succession of feeble resistances.

Third. A thickness of two inches is ample for shutters designed to stop the largest grape shot. With this thickness, they will be neither perforated nor deformed by anything less than cannon balls or shells. These shutters also, for the reasons just given, should be made of a single thickness. The firings show the necessity of concealing entirely, even from the smallest iron missile, their hinges and fastenings.

Third conclusion: shutters of 2″ amply thick.

Fourth. A wrought-iron plate of half an inch in thickness, is adequate to protect the outer margins, and the offsets of embrasures from injury by grape or canister shot.

Fourth conclusion: ½″ plate adequate to protect margins and offsets.

187. The brittleness of cast iron unfits it for use as a means of directly resisting the shock of cannon balls; this has long been well known. It was considered, however, worth while to try whether its cohesive strength might not be profited of, by diffusing the shock of a ball over a considerable surface of this material, through the intermedium of a thick plate of wrought iron. The compound plate of wrought iron interposed in the trials, was made up of eight half-inch plates, solidly riveted together, and a very even and uniform bearing of this 4-inch compound plate upon the cast iron, was secured—as perfect, certainly, as could be effected in general practice; nevertheless, the cast-iron block was always broken, splintered, or badly cracked, by a ball striking the wrought-iron plate in front of it.

Cast iron too brittle to resist direct shocks.

Resistance bad, even when protected by wrought iron.

This material may, of course, enter usefully into the construction of casemate embrasures, as dowels, ties, pintle-sockets, &c., but should not be relied on to resist the direct action of balls or shells.

Useful for dowels, &c.

SECTION II.

The size and form of exterior openings for embrasures.

Exterior opening should be a minimum.

188. The great importance of keeping the area of the outside openings of casemate embrasures at a minimum, will clearly appear from our experiments. *First*, the number of the enemy's missiles passing through the opening will, of course, increase with the enlargement of that area; and *secondly*, whatever may be the peculiar form of any embrasure, there must be a margin, larger as the opening is larger, where the walls, being materially weaker than elsewhere, will suffer the more from battering guns.

First reason.

Second reason.

Some foreign Eng'rs seem to have had but slight appreciation of importance of minimum exterior opening.

189. Although the first proposition seems not to need enunciation, and the second to be scarcely less self-evident, there appears to have been, with some foreign engineers, of the present day even, a very slight appreciation of the first, especially. They have taken some heed of the second, by giving thickness to the wall around, and by making the cheeks, sill, and lintel, of large blocks of stone; but, by inordinately spreading the exterior opening, they have shown that they looked upon the first as of little moment. For instance, in a large casemated battery erected in Europe within the last fifteen years, for the defence of one of the great ports, casemate embrasures have been introduced having an exterior opening of 54 square feet, and allowing the gun a horizontal traverse of only 40 degrees; while the embrasures of our second target, which allow all the elevation and depression necessary, and a lateral range of 60 degrees, have an exterior opening of only $8\frac{9}{10}$ square feet.

Example in point.

Embrasures of our second target.

Grave consequences of

190. It is easy to demonstrate the very grave con-

sequences involved in an unnecessary enlargement of this exterior opening. having too large opening.

Suppose a hundred-gun ship to be placed within good canister range of a casemated battery of about the ship's length and height; to the 50 guns of the ship's broadside, there would be opposed about 24 guns in two tiers, in the battery. The ship would fire each gun once in three minutes, or, 10 times in half an hour; the 50 guns would therefore make 500 discharges within that time. Shown by comparing effects of a 100 gun ship, firing canister against a battery, having casemates with openings like those of our 2d target, or like the European.

With 156* balls in each 32 pdr. canister (weighing in all 31½ lbs.), there would be thrown 78,000 balls in 30 minutes. Supposing one-half to miss the fort—which, considering the size of the object and the short distance, is a very large allowance—there would still remain the number of 39,000 balls to strike a surface of (say) 6000 square feet—that is, on each square foot . . . . . =6½ balls.

Or, within the exterior opening of one of the embrasures of our 2d target—of which the area is 8.9 square feet, there would fall—58 balls. All not intercepted by the gun itself, passing into the casemate among the men serving the guns.

Within the European embrasure above mentioned, having 54 square feet of opening, there would be received in half an hour 351 balls.

191. Should this idea be carried still further, as it ought, and the ship's canisters be filled with musket balls—each 32 pdr. canister holding 639 balls—the number of balls to the square foot of surface of the battery would be . . . . . 26 Suppose ship's canisters filled with musket balls.

* In the experiments at Gavre, in France, in 1837, with grape and canister shot, the canon-obusier 30 pdr., and the long 30 pdr. (French), both fired canisters containing each 120 iron balls of 1.05 inch in diameter.

The number received in half an hour within the exterior opening of the smaller embrasure would be, therefore 231

And within the larger embrasure in the same time 1404

Suppose ship's guns of larger calibre.

192. Nor, would it be fully measuring the effect of this exposure, to state that if the ship's guns were of the calibre of 8 inches—and there are even now many of larger calibre, and the tendency is to increase the calibre of both ship and shore-guns—supplied with canister holding 294 iron balls of 1.05 inch, or 1243 musket balls, the number of the former discharged in half an hour against each square foot would not be less than 12

Balls of 1.05″ diam.

Upon the exterior area of the smaller embrasure, not less than 106

And upon the large embrasure not less than 648

And the number of musket balls discharged in half an hour against each square foot from an 8-inch gun, would be not less than . . 51

Musket balls.

Upon the opening of the smaller embrasure not less than 453

And of the larger, not less than . . . 2754

In our experiments, musket balls passed through screens.

193. In our experiments, the musket balls fired in canisters, from a distance of 200 yards, passed clean through the screens made of pine boards one inch thick, whether they hit directly, or by reflection.

Balls not fused into clusters.

194. In no instance did we notice any fusion of these balls into clusters—the marks made by them on the target, and on the screen, being clearly the effects of single bullets.

Effects of canister balls of 1.05″ diam.

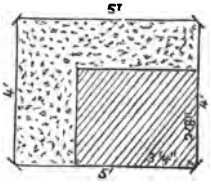
195. The effects of the small iron canister balls—diameter 1.05 inch, were considerable; when broken upon the cheeks of granite embrasures, the larger fragments passed through the screen; when the balls

struck brickwork or cement concrete, they produced craters about 3 inches in diameter by about 1½ inch deep; when they struck near the edges of the embrasures, they broke off considerable pieces, even from the granite—they have, therefore, as well as the musket balls, all the force necessary for the particular object in such an attack—namely, killing and wounding the men serving the guns of the fort, and thereby silencing its fire.

One of the consequences of expanding unnecessarily the outer opening, as exhibited by firings.

196. This is the place to recall the fact that by way of showing one of the consequences of an unnecessary expansion of the outer opening of an embrasure, a line was drawn on the target around two sides of the margin of Embrasure No. 7, so as to represent, very nearly, with the other two sides, the exterior opening of an embrasure of the first-built of

Fig. BB.



our casemated batteries (finished in 1810). The exterior opening of Embrasure No. 7, was 3′ 4″ by 2′ 8″, equal to $8\frac{9}{10}$ square feet; of the embrasure represented, in the way just stated, it was 5 feet by 4 feet—equal to 20 square feet.

The space between these two openings, that is, the excess of the larger over the smaller, amounting to 11.1 square feet, was struck by 108 balls in the course of our firing with spherical case, canister, and grape shot—this embrasure not having been more than any other the particular aim of this kind of firing.

The whole number of small balls fired at the two targets during all our firings—counting spherical

case filled with musket balls, canister shot of all sizes—including those filled with musket balls, and grape shot, was 32,555; that is to say, a number a little less than would be fired in 51 discharges of musket ball canister from 32 pounders: in other words, from a single "broadside" (plus one gun) from the ship: 639 by 51 = 32,589.

All these 108 balls excluded by Embrasure No. 7, would of course have entered, had its opening conformed to the larger outline; but even this larger outline scarcely exceeded one third of the exposure of the European embrasure, above mentioned; into which there would have passed, in the same time, according to the proportion, the number of 438 balls, over and above what passed into No. 7.

197. The trials, in firing from the target, proved that, if the embrasure were well built, the ball, in passing out from the gun, whether traversed, or elevated, or depressed to the extreme degree, might pass within about an inch of the outer edge of the embrasure, without injury by the blast of the gun to the material of the exterior margin. This may, therefore, be, with firm materials, a condition limiting the exterior opening. The minimum in the size of the throat is fixed by the space occupied by the muzzle of the gun, in its various positions; and as the area of the exterior opening will be the larger, as it is further from the throat, the latter should be placed as far to the front as the service of the gun and carriage will allow. The surfaces connecting the two areas, and which form the outer cheeks, sill, and lintel have generally been flaring planes; to which one great objection is that they reflect inward all missiles which inpinge thereon in lines, parallel or nearly so, to the directrix; so that virtually, as regards their admission into the casemate, the throat has had with that form

Condition limiting exterior opening.

Minimum throat.

The outer checks, the sill and lintel generally flaring.

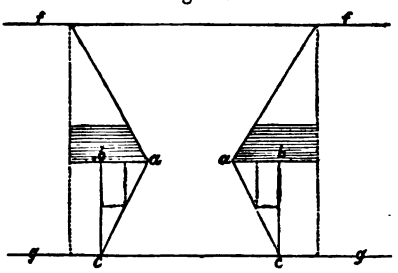
An objection to this form.

of embrasure, the full capacity of the exterior opening. This is very strikingly shown by the great number of balls thus reflected in our firings.

Suppose form of outer portion of embrasure changed.

198. If the outer portion of the embrasure be traced according to the bent line, *a b c*, instead of the

Fig. CC.



straight line, *a c*, it is evident that balls that would otherwise be reflected from the surface, *a c*, will be stopped on *a b*.

Compensate for loss of strength by change of form, by introducing a stronger material.

199. But the strength of the embrasure will be lessened by the removal of the material lying within the space, of which *a b c* is the horizontal section. This is, in fact, of little moment, because the strength lost by adopting the bent line *a b c* may be much more than supplied, by placing along *a b* a material more resisting than the masonry of which the flaring cheeks and throat-jambs have heretofore been made; and this we shall see is required by other considerations.

Strengthen throat by introducing a stronger material.

200. It is plain that if the thickness *f g*, of the wall, is needed to resist the battering of heavy balls, no ball striking anywhere between the two lines, *f g*—*f g*, will be adequately resisted with the old form *c a f*—*c a f*, of masonry embrasures. But by inserting a stronger material on each side of the throat, this deficiency of strength may be supplied, without filling up the space *a b c*, as it will need but a slight augmentation of the thickness of this stronger mate-

rial, to secure full compensation for the material thus omitted.

Advantages of new form for exterior.

201. It is also evident that by building in enough of the stronger material on each side of the throat, and adopting this new form, *a b c*, for the outer portion of the embrasure, there will be a general gain of strength, since up to the very edge of the throat plates there may be as much strength as there is beyond the lines *f g*—*f g*. At the same time, by substituting for the reflecting surface *a c* the plane *a b*, all missiles, whether large or small, that do not pass the throat without touching, will be stopped, either upon the outside of the wall or upon the throat plate.

Wrought iron the best material.

202. Our experiments show that wrought iron is the best material for insertion as above mentioned; and that a thickness of 8 inches of wrought iron, solidly backed with masonry, will resist an 8 inch solid ball fired with 10¼ lbs. of powder from a distance of 200 yards. It is necessary, as is also shown by the firings, that the plates of iron should have considerable breadth to prevent heavy balls from forcing themselves in between the inner edge and the masonry, thereby crowding the plate edgewise into the throat.

Plates should be broad.

Shoulders of masonry gave increased strength, but were objectionable.

203. With a view to gaining strength, by burying more deeply the iron throat plates in the masonry of the embrasure, rectangular shoulders of masonry were made to project from the solid of the cheek, into the space *a b c*, as seen by the dotted lines in the above figure. They stopped balls nearly as well as the unbroken surface, *a b*; and they augmented somewhat the resistance of the cheeks. Being enclosed in a facing of boiler iron they were not injured by small balls—but they increased the number of fragments cast into the casemate by heavier balls, and they do not prove to be an essential part of an improved em-

brasure. The additional strength imparted by them may be better secured in other ways. Embrasures Nos. 3, 7, 8, and 9, were thus constructed.

Offseted and flaring cheeks compared.

204. It is well to report in this place, a summary of the exact effects under our trials, of the broken, or offseted cheeks, as compared with the flaring ones: 1st, in stopping balls, and 2d, in glancing them into the casemate through the throat.

Flaring embrasures.

The number of balls from grape, canister, and spherical case shot, that were reflected from the cheeks of flaring embrasures (Nos. 1, 2, and 4), so that they passed through the throat into the casemate, was 40. The number of such shots stopped by these embrasures was 2. The fraction $\frac{40}{42}$ represents, therefore, the proportion reflected, and $\frac{2}{42}$ the proportion arrested.

Embrasures with offseted cheeks.

In the embrasures with broken, or offseted cheeks, the total number reflected through from the cheeks, offsets, &c., was 19—while the number stopped by them was 326—so that in this case, the fraction $\frac{19}{345}$ represents the proportion reflected, and $\frac{326}{345}$ the proportion stopped.

Proportions otherwise stated.

Or, these proportions may be represented thus:

Embrasure with flaring cheeks, 5 per ct. stopped.
95 per ct. reflected.

Embrasure with offseted cheeks, 94 per ct. stopped.
6 per ct. reflected.

As it was important to settle beyond question the effect, in arresting small missiles, of the offseted cheeks substituted for flaring ones, the firing of small balls was chiefly directed at the former, and hence the greater number of these balls that were received on the cheeks of that form.

Advantages of offsets.

205. It results from the facts and statements adduced thus far, that if, instead of giving to embrasures

flaring cheeks, the exterior cheeks be notched in, so to speak, at right angles or nearly so, to the plane of the throat; or, to repeat words often before used, be offseted, only those missiles that arrive directly within the area of the throat, will enter at all, excepting, indeed, a very small proportion that may be glanced in from the very edges of the outer opening.

Return to case of 100 gun ship.

206. In estimating the number that will pass directly through this throat-opening, from the 100 gun ship, in half an hour—we must take the clear area of this throat of the target embrasures—which was 1 ft. 6 in. wide, by 2 ft. 7 in. high, giving $3\frac{8}{10}$ square feet.

The comparative numbers.

The comparative numbers would be, therefore, as follows:

Gun 32 pdr., firing iron balls of 1.05 inch in diameter—

Through the throat of target embrasure	25 balls.
Within exterior opening of target embrasure	58 "
Within exterior opening of European embrasure	351 "

8 inch gun, firing iron balls of 1.05 inch in diameter—

Through the throat of target embrasure	46 balls.
Within exterior opening of target embrasure	106 "
Within exterior opening of European embrasure	648 "

Gun 32 pdr., firing canisters filled with musket balls—

Through the throat of target embrasure	101 balls.
Within exterior opening of target embrasure	231 "
Within exterior opening of European embrasure	1,404 "

8 inch gun, firing canisters filled with musket balls—

Through the throat of target embrasure	198 balls.
Within exterior opening of target embrasure	553 "
Within exterior opening of European embrasure	2,754 "

SECTION III.

Embrasure-shutters.

Even with the new form of embrasures, the gunners are much exposed.

207. We see, from the comparison just made, that, notwithstanding the very great advantage derived, first, from reducing the size of the exterior opening, and next, from changing the form of the portion of the embrasure exterior to the throat—the exposure of the men serving, even with the target embrasure, a casemate gun will still be great. They will be exposed during every half hour of action to 25—to 46—to 101, or to 198 balls, according to the various suppositions we have made, as to kind of gun and missile. From 1 to 6 balls entering the embrasure every minute, directly upon the place where the gunners are clustered, must make the service a very dangerous one—if indeed it could be continued with any effect in such peril.

2" shutters against grape and canister.

208. These, and such like considerations, led to the trial in the target of *embrasure-shutters;* and the experiments with these have shown that a thickness of 2 inches of wrought iron will certainly repel all such balls, as grape and canister.

1½" shutters against grape.

209. A grape shot of 4½ lbs. fired from an 8 inch Columbiad at the distance of 200 yards, produced no deforming, or otherwise injurious effect upon a wrought-iron shutter of 1½ inch in thickness, com-

posed of three ½ inch sheets. By simple arrangements, the centres of motion and the fastening bolts, can be screened from these small balls.

Shutters to be closed, except for a few instants at a time.

210. The shutter will be closed from the moment of firing until the gun is loaded—is again in battery, and ready to be again discharged; so that it will be for instants of time, only, that the gunners will be at all in danger from the enemy's small shots.

The spontaneous closing of the shutters may be made sure.

211. It cannot yet be asserted positively, that the shutters will close spontaneously at each discharge of the gun, because trial has not been made with shutters improved by the results of our latest experiments. But the tendency to close was so manifest, and so invariably exhibited, as to leave no doubt that a simpler mounting, and more accurate centering, would insure it.

This result very desirable.

212. This result is very desirable on account, not only of the quickness of this spontaneous action, as respects cover for the gunners, but because of the consequent exclusion of smoke. The same reaction of the air will drive back the shutter, that forces back into the casemate, sometimes a large part of the smoke of the discharge.

A spring upon the back of shutter.

213. In our firings from the embrasures, the shutters were, each time before the discharge, opened out by hand, and placed snugly against the cheeks; this might answer were they perfectly hung; but it is to be regretted that it did not occur to any one to leave them a short distance from the cheeks, in order that the outward blast of the gun, driving them forcibly against the cheeks, might cause a stronger reaction. A stiff spring upon the back of the shutter, keeping it, until forced, at a short distance from the cheek, will insure, it is believed, the requisite recoil; but with good centering this will hardly be necessary.

SECTION IV.

Throat of Embrasure.

Can the throat be safely reduced in width?

214. It was obviously a matter to be inquired into, whether or not, the throat itself could be reduced in width with safety.

To this end, some instructive trials were made (as before said) at my request, under the direction of Major J. G. Barnard, of the Corps of Engineers, then superintendent of the Military Academy.

Barnard

Cone of blast.

215. It was desired to learn something as to what may be called the cone of blast—which might have, perhaps, very near the mouth of the gun at any rate, limits pretty well defined, up to which we might safely bring the edge of our throat plates.

Experiments given before.

216. These experiments are given in the preceding pages in full detail; and offer an interesting study.

Results.

217. The principal results for our object are, that this cone diverges quickly from the mouth of the gun; that the action within its limits is very violent; that only very solid and firmly imbedded substances can be placed within the limits, or on their verge, near the mouth of the gun, since even the iron plates of a compound throat plate were there torn asunder by the blast—but that, undoubtedly, while a solid 8-inch plate firmly imbedded in masonry may be relied on at the same distance from the muzzle, and from the prolonged cylinder of the bore, that was found to test so severely the compound plates submitted to the trial—any less solid and firm material must be further removed. Of course, the nearer the edge of the throat plate is to the face of the muzzle, the nearer it may be to the prolonged cylinder.

SECTION V.

Thickness of Scarp.

Conditions fixing thickness of wall near embrasure.

218. The internal arrangement of the casemate, with reference to the handling of the gun, and especially the traversing it for horizontal scope; the place chosen for the axis of this horizontal motion; and the form and dimensions of the gun and carriage, including chassis, impose conditions affecting the thickness of the wall at, and immediately around, the embrasure; and affecting also the form of the latter.

5′ assumed.

219. A thickness there of five feet has been assumed in our constructions, and satisfies all these conditions well. But it has been a question of interest, increasing with the growing calibres of naval armaments, whether this thickness is now sufficient. And it was in consequence thereof that some very severe firing was directed against our 2d target. The gun was a 10-inch Columbiad, placed within 114 yards, firing solid balls, weighing 128 lbs., with a charge of 18 lbs. of powder.

Is that sufficient?

Experiments.

General conclusion.

220. The general conclusion from these trials is, that, whether of cement concrete, of bricks, or of hard stones, the portion of the wall at, and around, each embrasure, having the thickness of five feet only, should be no larger than is indispensable for the adaptation of the gun and carriage to the embrasure; if restricted to a small area, this thickness will suffice —not otherwise.

Under what circumstances 5′ suffice.

221. The thickness of five feet will resist a number of these balls, impinging in succession, on that space, provided the bond expand promptly, above, below, and on each side, into a thickness greater by some $2\frac{1}{2}$ ft., or 3 ft., or more. Were the wall no thicker,

generally, than five feet, being reinforced only by piers some 15 feet apart, it would soon be seriously damaged, by battering at short distances with such calibres.

Use of wrought-iron throat plates.

222. Wrought-iron throat plates of eight inches thickness, placed in the embrasure, and backed by three feet of solid masonry, will be equivalent, at least, to the five feet of masonry on either side; and, but for the great cost, this construction might be extended as far above, below, and on either hand, as necessary for the full and free use of the gun. The great additional expense would not, however, be compensated by any advantage of moment. In that case, the throat opening would be also the exterior opening of the embrasure, because the throat would lie in the outer surface of the wall. This opening being in area but 3.90 ft., would be a very great reduction in size, certainly, from that of the European embrasure (of 54 square feet) so often mentioned; and it would be less by five square feet, than the outside opening of the 2d target embrasures; but it would be no better than these last, in reference to the exclusion of an enemy's missiles, since, as we have seen, the offseted embrasure restricts the passage way to the area of the throat.

Except for great cost, the scarp might be wholly of iron.

223. Were it not for the vastly greater cost, the whole scarp might be faced with iron—indeed might be made of iron only; but, until there shall be much stronger reasons than now exist, or are now anticipated, for believing that well constructed masonry-batteries may be breached by naval broadsides, the cheaper construction may be safely followed—especially as, should such a necessity ever arise, they may be externally plated with iron.

No present necessity therefor.

To repeat—as to thickness of 5'.

224. To repeat: the scarp at the embrasure may be safely made of the thickness of five feet, provided

the thickness immediately above, below, and on the sides, be increased considerably. The space required to be of about this thickness, to accommodate advantageously the gun and carriage, is so small that it may be said to be part of the thicker surrounding mass, by which it really is supported in its resistance.

An interesting detail.

225. A detail of interest presented itself, in the course of the firing, in relation to the thickness of the scarp near the embrasure. It was this: a 24 pdr. ball, hitting the wall immediately in front of a recess made to receive the "tongue" of the chassis—which recess extended to within two feet of the outside of the wall—perforated this two feet, and, being less in diameter than the height of the "tongue hole," passed entirely through, without touching anywhere else. Had there been a carriage there, with its "pintle" in place, the latter would probably have been broken, and the carriage rendered for the time unserviceable. That "tongue hole" was seven inches high; it need be only about half as high; and there should be a thick plate of wrought iron buried in the wall, directly in front of the pintle, to stop such balls or larger ones.

Thickness in front of recess for tongue of carriage.

Iron plate should be inserted.

SECTION VI.

Effects of Firing from Casemates upon Ships.

Experiments show necessity of caution in using casemated batteries.

226. The firings from, and at, our embrasure targets, have given us, as we have seen, some instructive facts as to the necessity, in reference to the free use and efficient service of casemated batteries, of certain precautionary measures. Do not these results teach us also something in the opposite direction—something as to the offensive power of these batteries, not hitherto perhaps fully considered—especially in re-

Something also taught as to their offensive power.

ference to the effects of small missiles upon ships? For instance: On our hypothesis, the casemated battery of about equal external surface with the 100-gun ship—that is, of about 6000 square feet, would contain about 24 guns. Supposing these to be 32 pdrs., firing canisters containing 156 balls of 1″.05 each; and, as before, each gun firing 10 times in half an hour—allowing half the balls to miss the ship—there would be three balls received by each square foot, and as the port-holes are stated to be three feet high by three and a half feet (equal 10′.5 square feet), there would pass into each port 31 balls, and into the 50 ports 1550 balls, within the half hour.

Supposing a battery of 24 32 *pdrs.*, firing canisters filled with balls of 1.05″ diam., in contest with a 100 gun ship.

If the canisters were filled with musket balls, there would be 126 thrown into each port, and 6300 into the 50 ports.

Canisters of musket balls.

The guns being of 8-inch calibre, which is the common calibre of our important batteries, the number of 1″.05 balls to each port, would be 52; and to the 50 ports, 2600.

8″ guns. 1.05″ balls.

And, were the same guns to fire musket balls, in their canisters, there would be thrown into each port, 252 balls; and into the 50 ports, 12,600 balls in the half hour.

8″ guns. Musket balls.

227. The following table gives, in a compact form, a synopsis of the principal effects of the firing of small canister shots into embrasures, of several sizes; and also into the ports of ships, on our supposition of a 100-gun ship, in opposition for half an hour, at close quarters, to a 24-gun battery:—

Table of effects of small canister shot.

TABLE No. 19.

Giving the number of small iron and leaden canister balls, discharged in half an hour through the embrasures of a casemated battery, of 24 *guns, and through the port-holes of a ship in opposition, having* 50 *guns in each broadside; the total surface of fort and ship being each about* 6,000 *square feet. Specifying, in the case of* 32 *pounder and* 8*-inch gun, the numbers entering each embrasure and each port-hole.*

	No. entering each embrasure.		No. entering all the embrasures.		No. entering each port.		No entering all the ports.	
	Musket balls.	Iron balls of 1″.05.	Musket balls.	Iron balls of 1″.05.	Musket balls.	Iron balls of 1″.05.	Musket balls.	Iron balls of 1″.05.
FROM 32 PDR.								
Large embrasure of 54 square feet.	1,404	351	33,696	8,424				
Target embrasure with flaring cheeks.	231	58	5,544	1,392				
Target embrasure with offseted cheeks.	101	25	2,424	600				
Target embrasure with shutters.*	10	3	240	72				
Ship's port-holes.					126	31	6,300	1,550
FROM 8-INCH GUNS.								
Large embrasures of 54 square feet.	2,754	648	66,096	15,552				
Target embrasures with flaring cheeks.	453	106	10,872	2,544				
Target embrasures with offseted ch'ks.	198	46	4,752	1,104				
Target embrasure with shutters.*	20	5	480	120				
Ship's port-holes.					252	52	12,600	2,600

Table shows disadvantages of flaring cheeks, and advantages of shutters.

228. On an examination of the preceding table, we are surprised at the great numbers of these small, but fatal missiles, to which the gunners of the battery would be exposed, even with our comparatively very small target-embrasure. We see plainly the necessity of reducing that number, by removing the flaring outside cheeks; and, also, the vast advantage that the shutters afford of nullifying, nearly, the effects of this kind of fire.

Ships at short distances should fire

229. Indeed it is difficult to understand how a casemated battery having large embrasures, can be

* Supposing that for the instants the shutters are open, $\frac{1}{10}$ of the number falling within the area of the throat may enter the casemate.

canisters of musket balls.

served at all, after a ship has gained a position, within a short distance, and opened her fire of small canister balls. For the ship to fire grape, or *large* canister balls, would be to abuse her opportunity, since these larger balls would be no better in any such conflict, than the smaller ones, while they would be far less numerous. Musket balls, used as canister shot, would have all the force necessary; and we see by the table, that there would be thrown of these, in half an hour, into the casemate, through 24 embrasures, of 54 square feet of area each, by fifty 32 pdrs., no fewer than 33,696 — being 1,404 through each embrasure.

Ship would have advantage over battery with large embrasures.

230. Were the battery to retort upon the ship with the same missiles, the advantage would still be greatly with the ship, because against the 1,404 balls received by each embrasure, there would be thrown but 126 into each port; and into the 50 ports, there would be returned but 6,300 shots, against the above number of 33,696 poured into the 24 embrasures.

With improved embrasures, the advantage is greatly with battery.

231. On the reduction of the exposed opening of the embrasure, however, the proportion becomes less and less unfavorable to the battery—turning, before long, very decidedly in its favor. When the size is reduced to that of the 2d target embrasures, the ship will receive in her 50 ports 6,300, as before, against 5,544 entering the 24 embrasures of the battery. When the offseted cheeks are introduced, the 6,300 will stand against 2,424; and when the shutters also, the 6,300 are to be compared with 240 only.

Batteries should use small missiles against ships at short distances.

232. It may, therefore, become so much to the advantage of the battery, to resort to these missiles, especially with 8-inch guns, that the ship will be obliged either to give up the idea of close quarters,

or provide herself with quickly-moving port-shutters.

Calculations corroborated by our firings.

233. In corroboration of the preceding calculations, showing that they are not exaggerations, it is here stated as one of the recorded results of our firings, that the total number of small missiles that passed through the throats of our nine target embrasures without touching—the area of the throat being 3′.9—was 234. And, as before said, the whole of our firing at the target, with small balls, was equivalent to only a single broadside from the 50 guns of the ship.

SECTION VII.

Contests of Ships with each other.

Ship against ship.

234. Although it is not in the particular direction of our inquiries, we cannot help thinking, in this connection, that possibly our results and calculations may have some bearing, in certain cases, upon naval actions, ship against ship.

Incredibly small losses and injuries incurred.

235. We are told in naval histories of ships of war, lying engaged "*yard-arm and yard-arm*" for hours, and yet they report losses incredibly small, considering the time and the proximity; the ships, moreover, are seldom sunk, or otherwise destroyed, except by taking fire; and, though badly crippled, no doubt, make long voyages with no other than impromptu repairs.

Remark as to this curious result.

236. Without venturing to pry into this curious result, we may say, that if the want of more decided effects is the consequence of the want of more accurate aim in the solid balls (fired with some admixture probably of grape shot), this reason would apply, in a much slighter degree, to canister shot at short ranges,

since it would suffice if the gun were merely pointed *towards* the enemy's hull, for part of the cone of balls to fall upon her sides.

Could ship's crew survive 25,000 musket balls, entering her ports in one hour?

237. Is it not difficult to conceive how a ship's crew could survive one hour's firing, when there would be poured into her 50 ports more than 25,000 musket balls—into each port, more than 500 such balls?

Suggestion as to the proper charge and missiles in such conflicts.

238. Perhaps the suggestion may be pardoned, that in these close conflicts, a charge of powder, very much reduced in order not to endanger the gun, might be fired with a shell, and, in addition, a canister of musket balls. The latter would have all the force requisite to penetrate human flesh; and the shell would certainly have, at a distance so short, power to penetrate into the enemy's side far enough to cause great damage by explosion.

SECTION VIII.

History of Embrasure that has been introduced in the Coast Batteries of the United States.

Reference to history of embrasure appropriate.

239. It seems appropriate to this narrative of our recent trials of casemate embrasures, to refer briefly to the history of the embrasure that has been introduced in the coast batteries of the United States.

1808. The first casemated battery.

240. The first casemated battery was completed in 1808. It has two tiers of guns in casemates, and one in barbette. The exterior openings of the lower embrasures are 4′ 8″ by 6 feet, giving an area of 28 square feet; and of the 2d tier, 3′ 8″ by 5 feet—area 18½ square feet—the horizontal traverse of the guns being limited to 44 degrees.

Two others soon built.

241. Within three or four years of the time just mentioned, two other casemated batteries were built,

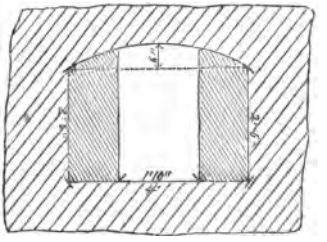
each having a single tier of guns in casemates, with exterior openings of 4′ 5″ by 5 feet, area 22 square feet; and with horizontal scope, one of about 42 degrees, and the other of about 45 degrees.

1815. 242. In 1815, the author of this report was called on to prepare a project for the defence of an important channel; and having been convinced, while employed as an assistant in the construction of two of the batteries just mentioned, that the principles, and the details, by which the embrasures and the dependent casemates had thus far been regulated, were erroneous and defective, set about a careful study of the conditions to be fulfilled in providing for the heavy guns of that period, mounted on a casemate carriage, that had already been proved and adopted. The result was an embrasure, having an exterior opening of 4 feet wide by 2′ 6″ high at the outside

Study of conditions necessary in providing for casemate gun.

The resulting embrasure.

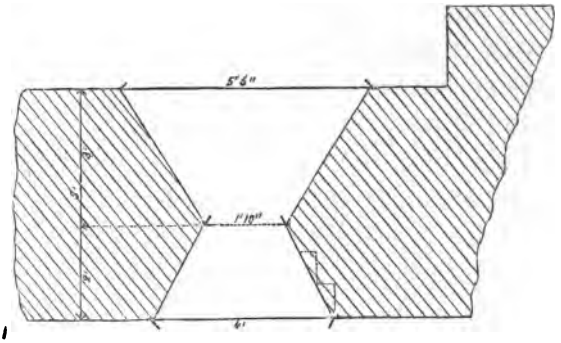
Fig. DD.



line of the cheeks, and 3 feet high at the key of the covering arch. The throat being 1′ 10″ wide. This provided for all the depression and elevation of the gun, that the carriage permitted; and also for a horizontal scope of full 60 degrees. Covered with a lintel, instead of an arch, the height of the exterior opening might be a little less than 3 feet.

Plan of embrasure. 243. The plan of this embrasure shows that the interior opening is 5′ 6″ wide, and that the plane of

Fig. EE.



the throat is within 2 feet of the outside of the wall, which, just at the embrasure, is 5 feet thick.

Modified for flanking guns.

244. A slight modification fitted this embrasure, when applied to flanking, or interior defence, to receive at first a cannonade of large calibre, and of later years, a howitzer instead. When these latter were liable to be assailed by musketry, the outer cheeks were made *en cremaillère* (notched), a long-known device.

Hesitation as to cheeks and throat.

245. It was with timidity and hesitation that the cheeks and throat of this embrasure were placed so near the track of the ball, when fired from the casemate, with the maximum obliquity, and the results of an early trial with experimental embrasures at Fort Monroe, gave some sanction to the doubt. The first two under trial, were built up with lime mortar, and were soon shaken to pieces by the blast of the gun. Another one, however, constructed of bricks laid in cement-mortar, sustained without injury several hundred discharges.*

Experiments at Fort Monroe.

* Lieut. Mansfield, then of the engineers, now Inspector General of the Army, in a letter dated early in 1830, at Fort Monroe, says: "1st. On my arrival at this place, "in 1828, there was then standing an experiment embrasure, built wholly of cut free-"stone, and of the same size as those here constructed—except that the cap was one "stone instead of an arch. Soon after the firing through this embrasure commenced

Results confirmed.

246. These last results have been confirmed wherever there has been practice from our embrasures; which, with immaterial differences, have since 1815 been constructed in all our casemated batteries, according to the preceding description.

Increase of strength to embrasure of 1815 expedient.

247. This being the state of things with these embrasures of 1815, an increase in their strength had, within a brief period, become expedient, not to say necessary, by the augmented calibres in ships' armaments.

How to give it.

248. It was considered that this strength might be given, perhaps, in part, by reducing the opening, and in part, by incorporating a stronger material in the portion where the quantity of masonry was unavoidably small, from the shape of the embrasure.

Reduction of exterior opening.

249. The resistance afforded by the existing embrasure to the blast of its own gun, justified the expectation that the exterior opening might be reduced nearly to an absolute minimum, and the facility

Use of iron.

with which large masses of iron are now wrought, suggested that by its use to a limited extent, not only might a greatly augmented strength be secured against the effects of a large ball, but small ones might be excluded altogether.

Target embrasures.

250. Our target embrasures were successively devised, further and further, to test these ideas. The

---

"it fell to pieces, by the mortar leaving the joints, outside of the plane of the throat, "and the stones separating and falling to the ground.

"2d. Another embrasure was constructed (of bricks) in the same place, and of the "same size, except as to the cap, which in this case was an arch of bricks only, laid "in a mixture of equal parts of mortar and humid cement. This embrasure fell to "pieces by the same means and in the same way.

"3d. A third embrasure was constructed of bricks, like the second—being laid in "cement. This has stood a trial of 270 discharges, and remains uninjured.

"4th. In each case there was about the same time allowed for the mortar and "cement to set."

The same officer, writing in August, 1830, says: "The same embrasure" (the 3d, above) "has had many severe trials again this spring, with a 32 pounder, and it has "not been in the least injured by the discharges."

trials sustained by them have become a part of the history of the American embrasure. And if there be any force in the deductions drawn in the preceding pages from these trials—the improvements they suggest as to the materials, dimensions, form, and details, are of importance.

Embrasure of 1855.

251. The embrasure applied since these experiments, to our casemated batteries, and which may be called the embrasure of 1855, devised in accordance with these deductions, and of which a model received your approval, is believed to satisfy completely all important conditions.

Concluding remark.

252. The greatly augmented strength and efficiency thus imparted to our system of national defence, will be due to the enlightened and liberal forecast which prompted you, as Secretary of War, to sanction and sustain the course of experiments of which this report is the record.

Respectfully submitted,

JOS. G. TOTTEN,
Bt. Brig. Gen. and Chief Engineer.

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SCALE OF 1″ TO 4′.

Plan and exterior elevation of first target.

PLATE III.

SCALE OF 1″ TO 4′.

Plan and exterior elevation of second target.

PLATE IV.

SCALE OF 2″ TO 1′.

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See Table No. 2; shots 8, 10.

Figs. 8, 9, 10, 11. Scale of $\frac{1}{4}$. } Profiles of craters formed by 42 Pdr. canister shot, weighing $5\frac{1}{10}$ ozs. each, in hydraulic concrete.

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Table No. 4; shot 27.

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Fig. 39. Scale of $\frac{1}{36}$. } Horizontal sections through the middle of Embrasures Nos. 1 and 2.

Figs. 40, 41. Scale of $\frac{1}{36}$. } Vertical sections through the axes of embrasures Nos. 3 and 4.

Figs. 42, 43. Scale of $\frac{1}{36}$. } Vertical sections of craters of 42 Pdr. solid shot in lead concrete.

For Fig. 42, see shot 70 of Table 7: for Fig. 43, see shot 67 of Table 7.

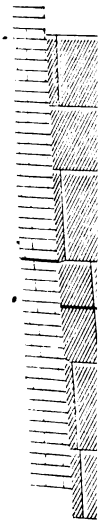
PLATE IX.

Fig. 67. Outside of outer set of plates, as they were set up before the gun. Before firing, the heads of all the rivets, except that at *a*, were broken off.

Fig. 68. Inside of outer set of plates. Heads of rivets whole, except those at *c* and *d*.

Fig. 69. Outside of inner set of plates. Heads of rivets whole, ex broken, and *e* partly so; *c* and *d* were points where the had been struck by shot.

Fig. 70. Inside of inner set of plates. Heads of all the rivets brok except those at *a* and *b*.



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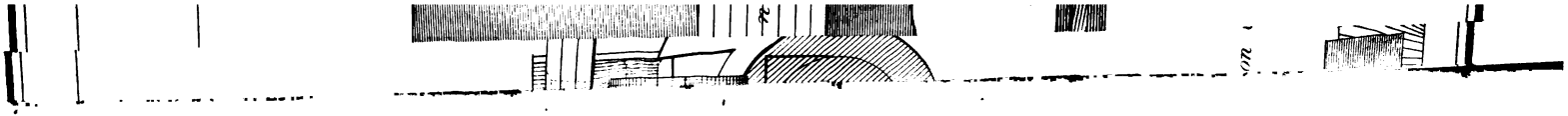
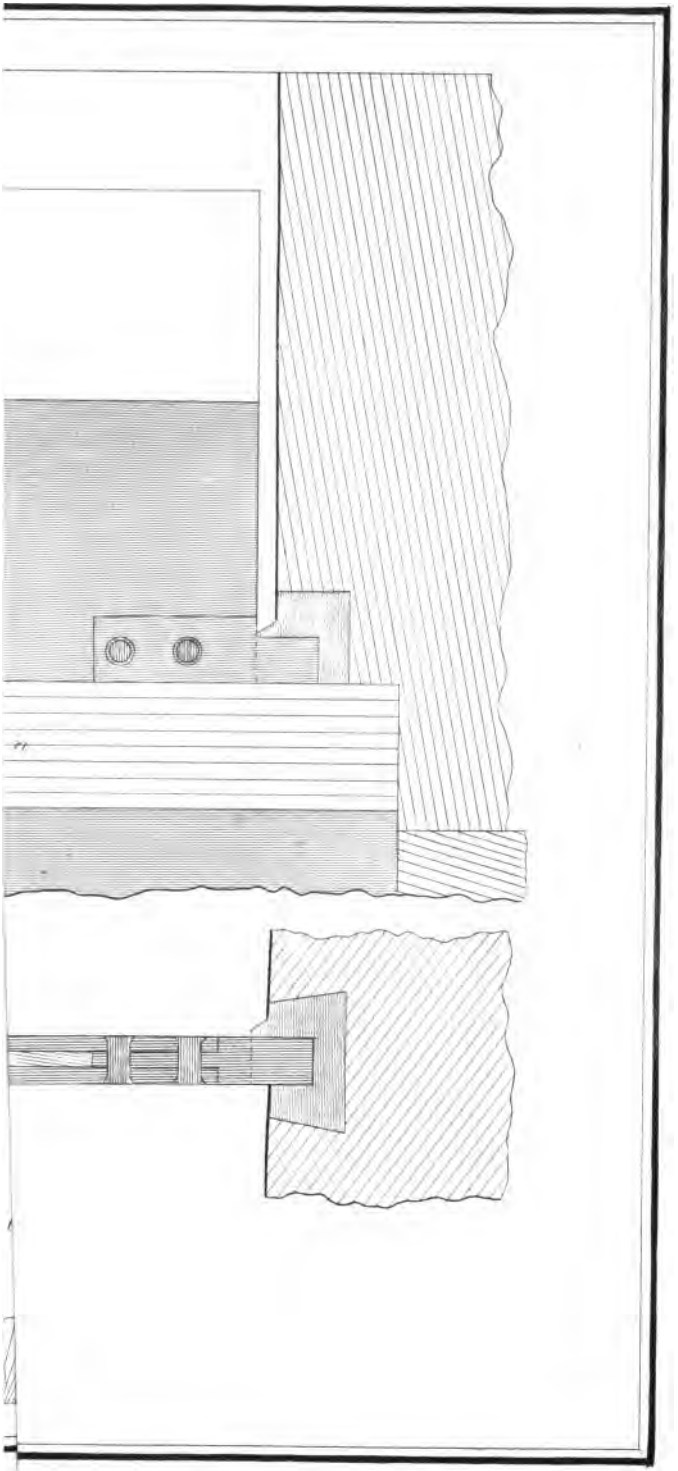


Plate IV.



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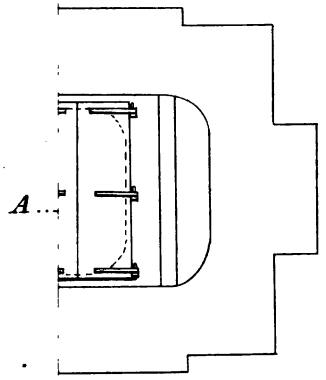

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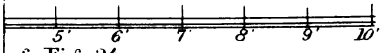
Face of wall.

Elevation



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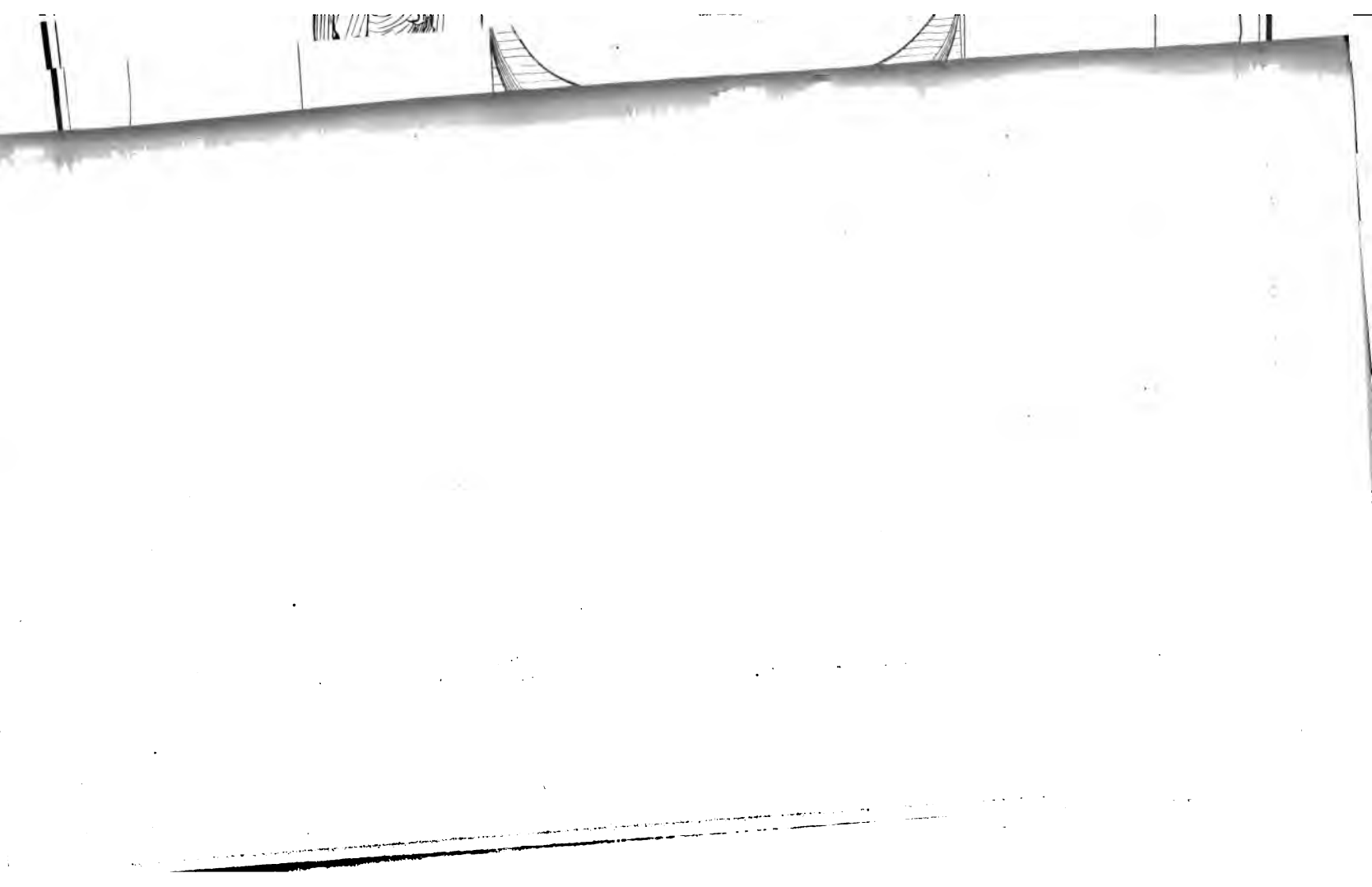

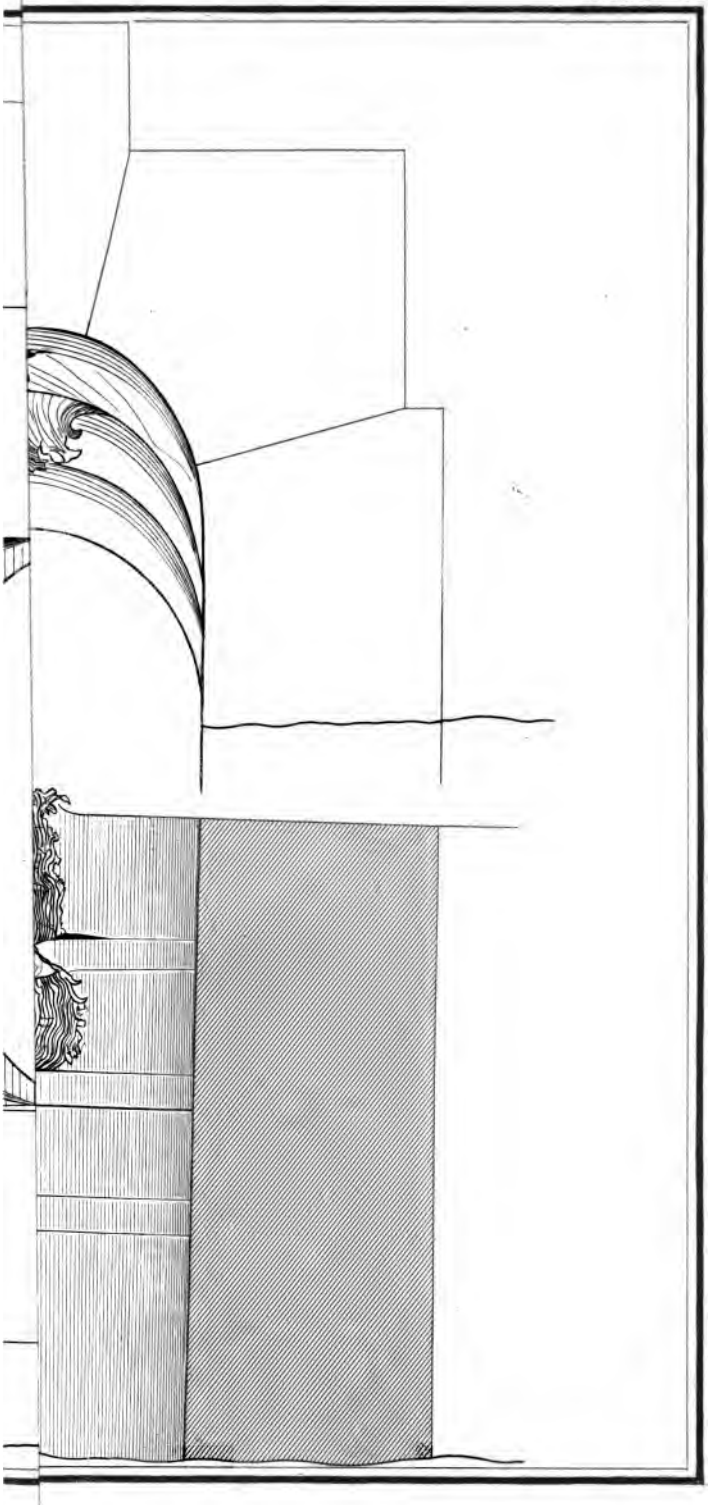

Fig. 42.

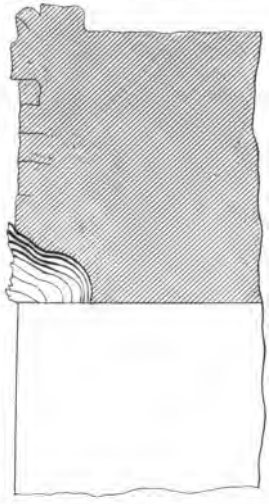

Fig. 43.

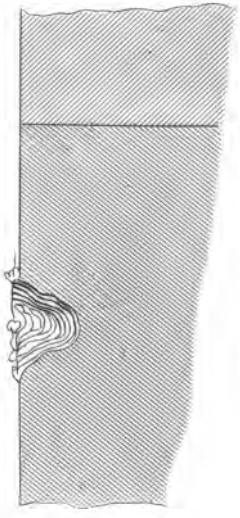

Fig. 68.

Fig. 69.

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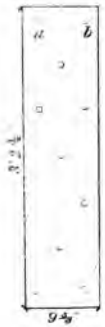
Fig. 70.



xis of gun